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The Geographical Evolution of the North Sea Basin.

By

L. Dudley Stamp,
University of London.

I. Introduction.

REGARDED from one point of view the basin occupied by the North Sea is geologically very ancient. When the Armorican earth movements brought to a close the long quiet period during which the Coal Measures were deposited, they resulted in the formation of lines of mountains across what is now the northern part of Central Europe and left to the north a wide, shallow basin. Though closed to the north by the Caledonian mountains which stretched from Scotland to Norway, the desert-girt basin thus occupied by the Permian Sea included practically the whole of the area now lying beneath the waters of the North Sea, though stretching far beyond the present limits of that sea.

The great structural units which limit the North Sea basin thus date from the periods of the Caledonian and Armorican earth movements and the basin has persisted, though in varied forms, as a physiographic unit from that time to the present.

From another point of view, however, the North Sea is a very recent, almost a modern phenomenon. There is little doubt that man, who had already advanced beyond the use of primitive stone implements, wandered on dry land all over the southern half of the basin and built his primitive homes amongst the forests of the Dogger Bank, finding as the principal obstacles to his wanderings the lower, marshy, courses of the Rhine, the Thames and the Ouse. It is only very recently that it has been recognized that the topography of the floor of the North Sea is that of a submerged plain and that the sediments of the sea-floor have undergone but limited changes since the submergence. It is within the last ten years also that the discovery of human artefacts in beds interstratified with the glacial deposits of East Anglia has permitted at least a partial solution of the longstanding mystery of the relationship between the climatic pulsations of northern Europe

and the cultural evolution of Stone Age man. The time would seem to be opportune, therefore, to attempt in the light of these recent discoveries to trace the geographical evolution of the North Sea Basin. The reconstruction must, in any case, be tentative for many major problems await solution. For example, though the four glacial periods of the Alps have long been known and clearly demonstrated, and though there is increasing general agreement that eastern England was similarly affected by four main glacial periods, the apparently obvious correlation cannot be directly made and would, indeed, appear to be a wrong one. Although the attempt is here made to trace the history of the Basin in true sequence, a note is made where possible of divergent views. It has proved out of the question to append full references to the relevant literature because of the immense number of writings involved. The footnotes refer, therefore, to but a few papers of outstanding significance.

II. The North Sea Basin from Carboniferous times to the Miocene.

In Coal Measure times there existed a great continent to the north linking Scotland and Scandinavia and built up of mountains of Caledonian age. From this continent rivers drained southwards and had built up, in Britain, the great delta of Millstone Grit — a delta which later became the home of Coal Measure forests. The old land-ridge of St. George's Land stretched across central England from east to west and to the south of this island also grew Coal Measure forests.

The Armorican or Hercynean earth movements defined much more clearly the North Sea Basin. The *massif* of Wales was further enlarged; the Pennines of England arose to form a natural western limit of the basin; the Amorican mountains of the Ardennes, Central and Southern Germany defined it to the south. The Basin itself became occupied by the 'Germano-British' sea of Permian times and later by the varied desert lake areas and the Muschelkalk Sea of the Trias. Throughout Jurassic times the basin persisted; the Cretaceous seas occupied it and in the heart of the basin (Danian of Denmark) we find the least disturbed transition from Cretaceous to Eocene beds. When the gentle earth movements of Eocene and Oligocene times culminated in the great Alpine storm of Miocene times, the ancient blocks of Highland Britain and Scandinavia remained but little altered and so continue to form the natural limits of the North Sea Basin. Along the southern margins folding movements were more marked and important changes occurred in Southern England — in the further uplift of the Weald and the folding of the Isle of Wight. The story of the early North Sea can be traced in the works of several geologists[1]) and it will suffice to begin this study with conditions as they were in the Miocene, after

[1]) See especially M. Gignoux, Géologie Stratigraphique, 2nd Ed. 1936. L. D. Stamp, An Introduction to Stratigraphy, 2nd Ed., 1935. L. J. Wills, Physiographical Evolution of Britain, 1929.

the last great period of earth-building movements. The accompanying map, based on that of Gignoux, modified by Morley Davies[2]) illustrates the geography of the North Sea Basin at that time.

III. The North Sea Basin in Pliocene Times.

Lower Pliocene (Diestian) Times.

The great Alpine storm of Miocene times had spent its force before the end of that period. The effect of the great upheaval in Central Europe had been, as already shown, to restrict the Miocene North Sea

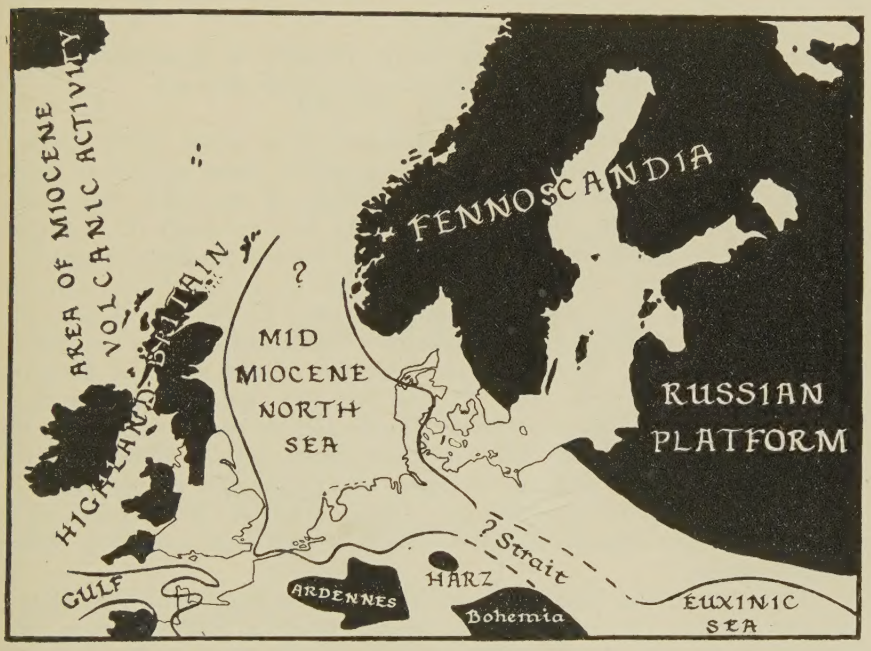

Fig. 1. The Middle Miocene North Sea, showing in black the hosts or ancient blocks by which the basin is naturally bounded (after Gignoux and Morley Davies).

to the centre of the Basin with the result that Miocene deposits, except for certain possible representatives, are unknown in Britain[3]). The Alpine earth movements, though their power was almost exhausted before they reached as far north as the south of England and the North Sea, resulted undoubtedly in intensifying the pre-existing trough of the London Basin and the existing anticlinal arch of the Weald and

[2]) Tertiary Faunas, Vol. II, 1934, p. 166.

[3]) The 'Boxstones' or sandstone pebbles with a Miocene fauna found at the base of the Crag in East Anglia show that Miocene beds were formed in the North Sea.

caused severe folding in the Isle of Purbeck and the Isle of Wight, as suggested in Fig. 2.

Since Miocene times it is important to remember that, although there have been no major folding movements, earth movements of three types may have, and probably have all, occurred. These three types are:—

a) renewed folding along Alpine lines, i. e., an intensification of anticlinal or synclinal structures of Miocene date,

b) tilting, or differential upheaval or subsidence over large areas — some of the tilting possibly isostatic and due to the weight of great masses of ice,

c) vertical or eustatic movements of elevation or depression resulting in changes in the relative level of land and sea.

The earth movements of later Miocene times, which threw the sea of the Wealden ridge were of the first type but there appears to have followed a general subsidence — a movement of the third type. The marine waters of the Diestian North Sea thus invaded the London Basin syncline and have left traces of their former presence in patches of ferruginous sand with marine fossils high up on the North Downs — the Lenham Beds. In an important paper, Dr. S. W. Wooldridge pieced together the fragmentary evidence and traced the shorelines of this sea[4]). Whilst the Diestian age of the Lenham Beds of East Kent is admitted, it is claimed by some palaeontologists that similar beds further west at Netley Heath and on the northern side of the basin at Rothamsted (Hertfordshire) have a later Pliocene (Red Crag) fauna[5]). The evidence is slight, but this would simply mean a persistence of the Pliocene Sea for longer than Dr. Wooldridge imagined in the London Basin, or even a westward extension after Diestian times.

The fauna of the English Diestian includes a considerable percentage of warm-water species and there is a marked affinity between the faunas of the East Anglian Pliocene and the St. Earth beds of Cornwall (deeper water Mio-Pliocene). It is accordingly probable that the Diestian North Sea was connected with the warmer Western Sea. This connexion may have been through the western end of the London Basin to the Bristol Channel or, as Dr. Wooldridge believes, further to the south through a synclinal trough west of Basingstoke[6]). That an arm of the Diestian Sea extended south of the Weald is evidenced by the discovery of a Diestian fauna near Beachy Head[7]).

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[4]) The Pliocene History of the London Basin, *Proc. Geol. Assoc.* vol. XXXVIII, 1927, pp. 49-132.

[5]) A. Morley Davies, Tertiary Faunas, Vol. II, 1934, p. 207.

[6]) *Op. cit.* p. 95.

[7]) F. H. Edmunds *Geol. Mag.*, 1927, p. 287.

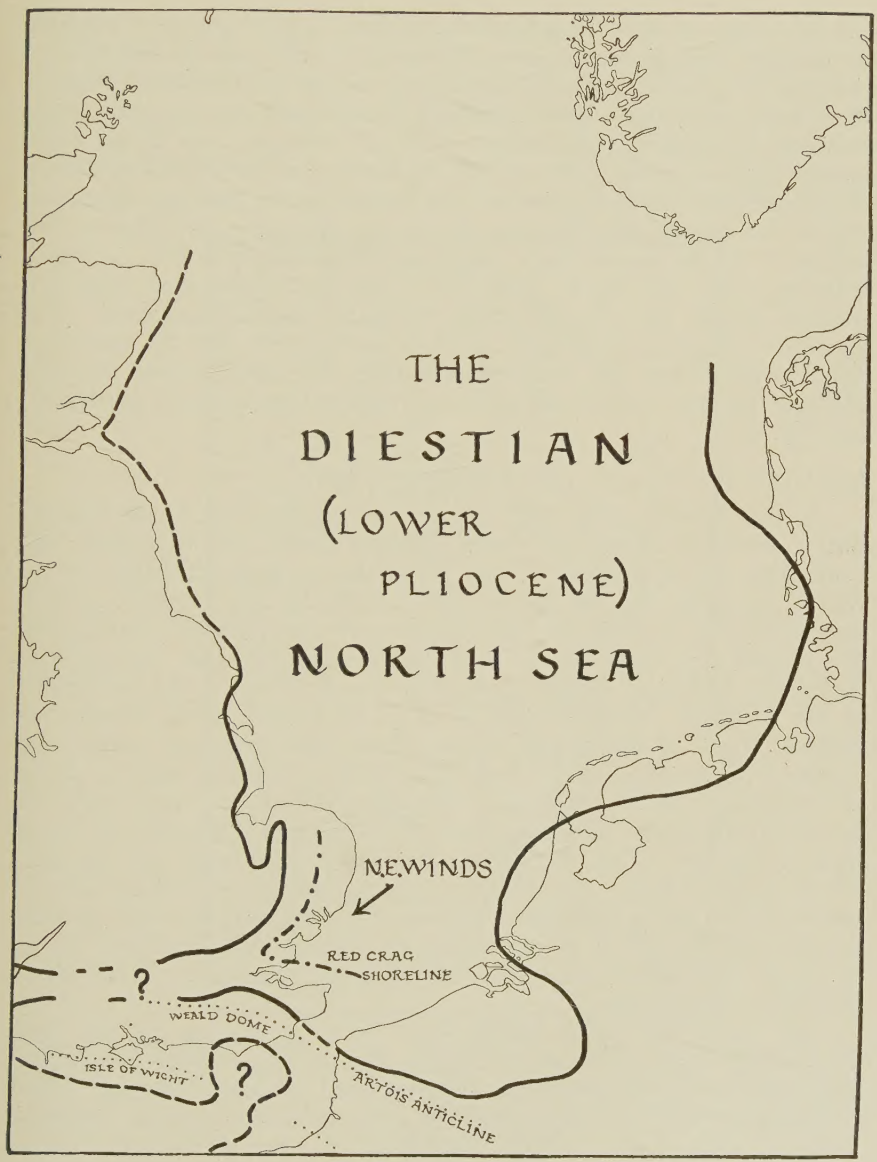

Fig. 2. The early Pliocene geography of the North Sea Basin.

Middle Pliocene (Gedgravian or Coralline Crag) Times.

Wherever or whatever may have been the connexion between the Diestian North Sea and warmer waters, later in the Pliocene the connexion was severed. It may still have been open at the time of

the deposition of the Coralline Crag of East Anglia and the Casterlian of Belgium, but from that time onwards the Pliocene deposits round the North Sea show a steadily decreasing percentage of southern forms. If it had not already been breached, the Caledonian mountain ridge between the Scottish Highlands and Scandinavia was now severed and communication established with the cold waters of the Northern Ocean. Blocks of rock with Casterlian fossils have been dredged from the North Sea east of the Orkneys, so the sea probably extended to that latitude. In the south there seems to have been renewed, if slight, warping along the Alpine fold lines. The Wealden-Artois ridge was slightly raised, the London Basin Syncline slightly deepened. The Casterlian deposits of Belgium thicken northwards. At the same time the Pliocene North Sea had retreated from Germany, where the only Pliocene known is from the island of Sylt in the extreme north-west (see Fig. 2).

Middle Pliocene (Red Crag) Times.

As the Pliocene time wore on, the sea retreated from the London Basin, retreated northwards from Belgium (where the Scaldisian and Poederlian are equivalents of the Waltonian or *lower* horizons of the Red Crag only), and the Upper Red Crag North Sea occupied an area approximating to that of the present-day sea, though overlapping the present-day coast-line in East Anglia and Holland, (Amstelian). Again the Red Crag fossils must occur on the floor of the North Sea as far north as Aberdeenshire, as they are found in the North Sea Glacial drifts of the coasts. Apart from the increasing number of northern forms amongst the Red Crag *mollusca* there is other evidence of oncoming Arctic conditions. Boulders of foreign rock, some of Scandinavian origin, sometimes exceeding a foot in diameter, are found both at the base of the Red Crag, and scattered through the deposits. There is little doubt that these were dropped from melting icebergs which drifted across from the Scandinavian coast and they bear witness to the early formation of glaciers or an ice-cap over Norway. There are some who believe that this cold phase is equivalent of the Günz glaciation of the Alps.

The three sub-stages which have been recognized in the Red Crag (from the oldest to youngest, Waltonian, Newbournian and Butleyan) are nowhere found superimposed on one another. Their arrangement with the oldest beds in the south-west and the youngest to the north-east bear out the conception that the shelly Red Crag is a shore deposit left by the sea retreating to the north-east, and Harmer long ago attributed the accumulation to the work of easterly gales. The fossils are usually abraded or broken.

Mr. J. Reid Moir claims that flints found below the Red Crag show evidence of human workmanship. If so, this is the earliest evidence of man in Britain[8]).

[8]) See the long series of papers in the *Proc. Prehistoric Society of East Anglia, Proc. Royal Soc.*, and elsewhere.

Upper Pliocene (Norwich Crag) Times.

The Norwich Crag occupies a large area to the *north* of the Red Crag and affords evidence of the continued retreat of the Pliocene North Sea in that direction. The fauna is not only more modern but is markedly more northern in character so that the climate would seem to have been becoming steadily colder. The Norwich Crag is more extensive in East Anglia than the earlier crags and thickens to the

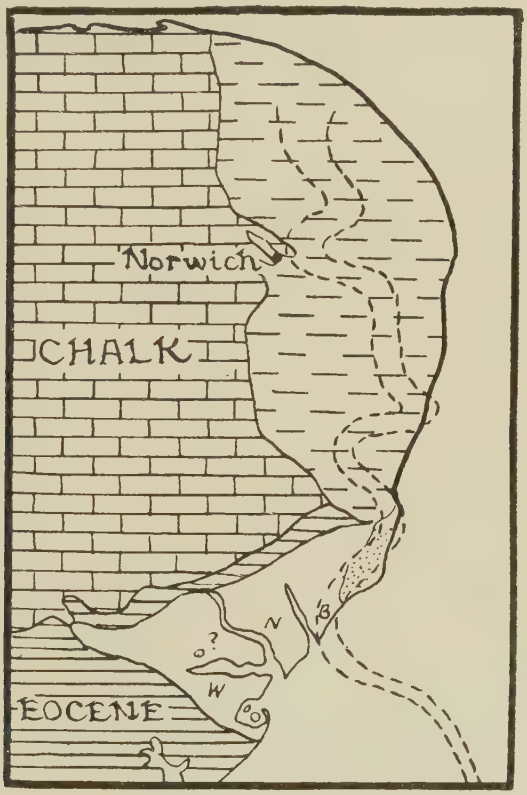

Fig. 3. The "Chillesford River" according to F. W. Harmer. The solid geology of East Anglia is also shown:— dotted = Coralline Crag; blank = Red Crag (W, Waltonian; N, Newbournian; B, Butleyan); interrupted lines = Norwich Crag. (From Stamp's "Introduction to Stratigraphy" by permission of Murby & Co.).

north and east — that is towards the centre of the North Sea Basin — and its sands and clays with occasional pebble beds are more clearly bedded than the shore deposits of the Red Crag.

Upper Pliocene (Chillesford Beds) Times.

The Chillesford Beds of Norfolk and Suffolk rest irregularly on either the Red or Norwich Crags and consist of fine, micaceous sands sometimes full of shells, often overlain by estuarine clays. The outcrop

can be followed along a sinuous course from south to north and Harmer believed that they were laid down in a distributory of a delta — the delta of the ancient Rhine. It is important to remember that the retreat of the sea from the Wealden uplift and the London Basin must have synchronized with the development of those consequent streams and the advancement of the Wealden drainage pattern which has remained the classic example of such development since it was first described by W. M. Davis. The Chillesford Beds may represent

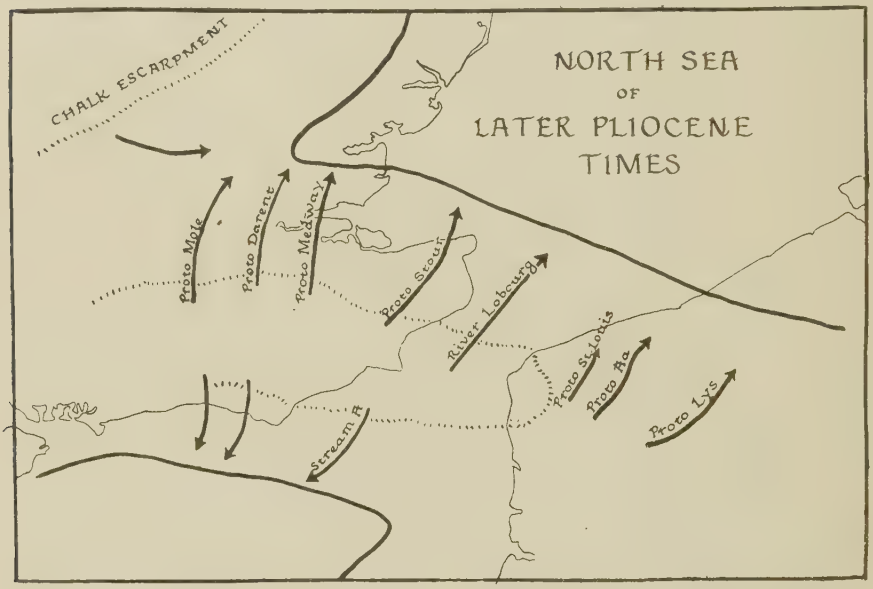

Fig. 4. The later Pliocene geography of south-eastern England (after Stamp, Geog. Journ. LXX, 1927 and Wooldridge, Proc. Geol. Assoc. XXXVIII, 1927).

the estuarine deposits of these Wealden rivers. On the other hand although the "Chillesford Beds" have long been accepted as a distinct group, they do comprise isolated or separated patches of sands which may be of different ages. It is interesting that the sands show varves or seasonal laminae.

Upper Pliocene (Weybourn Crag) Times.

The Weybourn Crag is found only on the Norfolk coast. Amongst the fossils there are less than 10 % of extinct forms; no southern forms survive but there is a further influx of "northern" forms including *Tellina balthica* which suddenly becomes extremely abundant. Seventy per cent. of Weybourn Crag fossils are of species still living in British seas and the deposits suggest that conditions in the North Sea were not markedly different from those of the present day. It is claimed that the old shore-line of buried cliffs with accompanying beach deposits, running from Hessle on the Humber, inland to Beverley and to the coast again at Sewerby, is approximately of this date.

Upper Pliocene (Cromerian) Times.

The interesting Cromer Forest Bed Series is only seen on the Norfolk coast, where it is overlain by Glacial Deposits. There is an impersistent Lower Freshwater Bed, succeeded by the Estuarine layer or Forest Bed proper. The Upper Freshwater Bed lies in erosion hollows on the surface of the Forest Bed. The whole has been regarded, as with the Chillesford Beds, as having been formed in the delta of a river which was possibly the ancestor of the Rhine. The Forest Bed is particularly interesting in that it consists of clays with sandy and lignitic seams and yields the stools and boles of trees and other plant remains of which no less than 135 species of flowering plants alone have been recognized — largely from seeds[9]). These are nearly all species living in Britain now and the inference is that climatic conditions must have been almost the same as those of the same area to-day. The fact that the few associated marine molluscs are northern forms merely indicates that the only open sea connexion was to the north. The freshwater shells, on the other hand, have a more southern aspect, as one would expect, with free land or freshwater communication with the south.

Roaming over the land which thus linked England with Holland and Germany were such mammals as *Elephas antiquus, E. meridionalis, Hippopotamus amphibius, Rhinoceros etruscus, Ursus spelacus* and some sixty others whose remains have been found in the Forest Bed and show that clearly there was uninterrupted communication by land between Britain and the Continent. It was formerly thought that because this land fauna is a *southern* one that it indicated a return to warmer conditions and that it might represent a first 'interglacial' period. But the associated land flora shows that the climate was the climate of to-day — perhaps slightly more Continental with colder winters and warmer summers as one would expect with Britain part of the Continent; the associated marine fauna is a northern one. The explanation is afforded by the distribution of land and sea — free land and freshwater communication with the south, free sea communication with the north only. Although this was realized by Clement Reid in his great work on the Pliocene Deposits of Britain (1890)[10]) it was rather overlooked till recalled by Boswell in 1931[11]). Only recently has evidence been collected that man himself was among the denizens of the Cromerian forests or plains. The

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[9]) E. M. Reid. In this important paper Mrs. Reid traces the effect of the general increase of cold throughout the Pliocene in causing the southward migration of warmth-loving species, with the result that the Lower Pliocene flora of Western Europe survives to-day mainly on the Himalayas and mountains of Western China at heights of 5000 to 6000 feet, having migrated south against the cold and then migrated *upwards* on mountain slopes against increasing heat of post-glacial times. *Quart. Jour. Geol. Soc.*, LXXVI (1920) 1921 pp. 145-146.

[10]) *Mem. Geol. Survey.* — See also "Submerged Forests" (1913).

[11]) *Proc. Geol. Assoc.*, xiii, 1931 pp. 89-90.

implements discovered in association [12]) with the Forest Bed are of Pre-Chellian Types, so that the users of the Strepyan implements of Belgium or the eoliths of the North Downs may have been contemporaries of the dwellers in Cromerian forests.

The Pitdown skull *(Eoanthropus dawsoni)* though apparently occurring in Pleistocene deposits of the Weald, is associated with derived Pliocene mammalian remains and it would seem that before the close of the Pliocene man himself was widespread in Britain.

The Cromer Forest Bed is succeeded by the *Leda myalis* bed of the Norfolk cliffs. Its cold water marine molluscs show the nearer approach of Arctic conditions but the old statement that it shows a *return* to cold conditions after the 'milder' Cromerian must be discounted. It is frequently grouped with the Pleistocene.

Summarizing, during the whole of the Pliocene conditions seem to have become steadily colder. There is little evidence of a distinct glacial period, though icebergs seem to have drifted across the North Sea from an ice-cap in Scandinavia, which may have been the contemporary of the Günz glaciers of the Alps.

IV. The North Sea Basin in Quaternary Times.

The First British Glaciation — the advance of the North Sea Ice.

There can be little doubt that the first accumulation of ice in Northern Europe was on the lofty Scandinavian mountains. At an early stage valley glaciers from the central mass must have stretched down into the Norwegian fiords and have given birth to icebergs which drifted across the North Sea. It was probably these bergs which dropped the erratic blocks of Scandinavian origin found at the base of the English Pliocene Crags[13]. This early glaciation of Scandinavia may have been contemporary with the Günz of first glaciation of the Alps. If so, its effect in Britain is limited to the gradual lowering of temperature seen throughout the Pliocene.

In East Anglia the *Leda (Yoldia) myalis* Bed with its cold marine fauna is succeeded by the Arctic Freshwater Bed — a bed of limited extent but great interest. It is usually taken as the oldest of East Anglian Pleistocene deposits and indicates a widespread elevation of the sea-floor and the corresponding extension of the land surface. The Arctic Freshwater Bed leaves no doubt as to the Arctic conditions then prevailing on land — with such present-day plants of the tundra as *Betula nana* (Arctic Birch) and *Salix polaris* (Arctic Willow). The elevation which thus changed part of East Anglia from the floor of the North Sea to a willow-birch swamp forest was probably that which

[12]) Not actually found in the bed, but in a gravel believed to be that at the base of the Forest Bed.

[13]) An elevated ice cap would give rise to strong out-blowing winds which would drive the icebergs across to Britain. *Cf.* Antarctica — F. Debenham Report Brit. Ass. Adv. Sci. Norwich 1935.

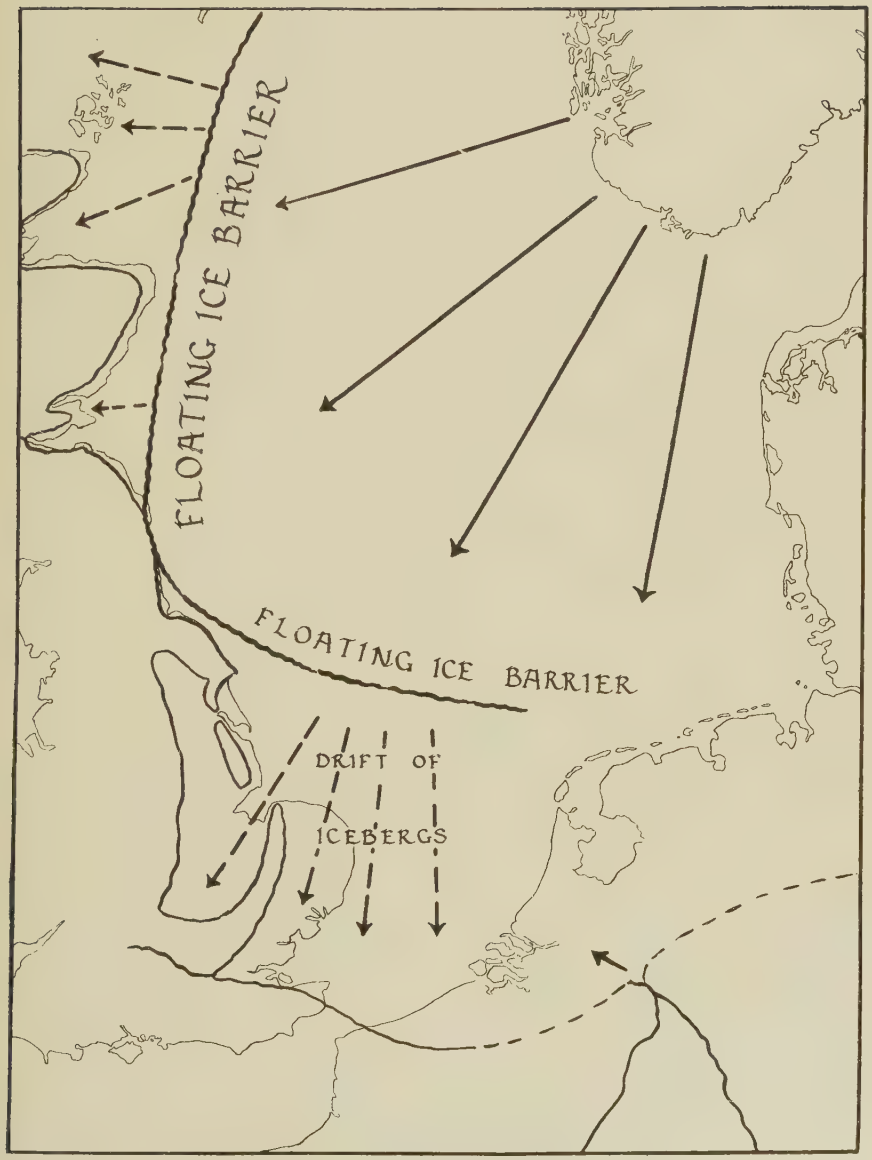

Fig. 5. The North Sea at the time of the First British Glaciation.

also caused the elevation of the well-known pre-glacial raised beach found along so many parts of the British coast, now about 12 feet above sea-level. If one accepts the idea of a rather delicate isostatic balance it may be hazarded that the increasing weight of ice over Scandinavia at first caused a compensatory upward tilt in Britain, followed, as the area covered by the ice-cap and its weight increased,

to a general and widespread depression. Whether that is so or not, the continued accumulation of ice in Scandinavia was accompanied by a general submergence of the land of Eastern England. We can picture a great ice-barrier generally spreading westwards across the North Sea (floating as does the Ross Barrier of the Antarctic at the present day) and giving off huge icebergs which deposited their load of debris over the submerged low ground of eastern Norfolk and Suffolk. In this way was formed the Norwich brick-earth and probably the Cromer Till — unstratified deposits with scattered Scandinavian erratics which have every appearance of having been deposited under water and not by the melting of a glacier *in situ*. Icebergs seem to have drifted up the submerged Wash and far into the southern Midlands[14]).

British—North Sea Pleistocene Chronology.

Solomon [15]) 1932	Boswell [16]) 1932	Cultural Stages [16])	Possible correlation with J. Geikie's European [17]) Glaciations	Correlation according to Baak [18]) 1936
	? Fifth Glacial			
	? Fourth Interglacial			
Hessle Glacier	Fourth (British) Glacial	Magdalenian etc.	Mecklemburgian Glaciation	
	Third Interglacial	Aurignacian Mousterian		
Little Eastern Glacier	Third (British) Glacial	Mousterian	Polandian Glaciation	Würm
	Second Interglacial	Achenlian	[Elmian]	Elmian
Great Eastern Glacier	Second (British) Glacial	Chellian	Saxonian or Great Glaciation	Riss
	First Interglacial	Chellian		
North Sea Glacier	First (British) Glacial	Pre-Chellian	Scanian Glaciation	Mindel

Icebergs similarly drifted across to Scotland and deposited their debris around the Orkneys and in the Moray Firth and it is possible

[14]) Boswell *op. cit.* see also F. W. Harmer Proc. Yorks. Geol. Soc. XXI 1928 pp. 79-150 (with coloured map of erratics).
[15]) J. D. Solomon, Proc. Geol. Assoc. XLIII, 1932, pp. 241-271.
[16]) P. G. H. Boswell, Report Brit. Ass. Adv. Sci., York 1932; Proc. Geol. Assoc. XLII, 1931, pp. 87-111.
[17]) Jour. Geol., III, 1895, pp. 241.
[18]) *Vide infra.*

that, at least at one stage, the ice-sheet itself impinged on the shores of Durham and Yorkshire. At the same time there was a feeble accumulation of ice in Britain itself, the evidence for which is not very clear.

During this period there is every reason to believe that the Thames and Rhine drained northwards into the North Sea which was *not* completely blocked by an ice-sheet. Clearly the Thames must have been at a high level above its present valley and some of the 'plateau gravels' may date from that period.

In East Anglia the Norwich brick-earth — the subaqueous boulder clay of the Scandinavian ice — is succeeded by the well-known glacial sands and gravels. These afford the evidence of the first 'inter-glacial' period and are attributed to the meeting of ice and the consequent deposition of out-wash in a North Sea Basin which was probably a shallow sea. It is well known that, as the ice-cap over Scandinavia grew, its centre (of maximum accumulation) shifted gradually towards the east until at a later stage it was over the Gulf of Bothnia. Again allowing a delicate isostatic balance, the surface of Britain (and with it the British shores of the North Sea) may have risen while Scandinavia sank. Thus the stage was set for the oncoming of the second British Glaciation.

The Second British Glaciation — the advance of the Great Eastern Glacier.

The oncoming of this period was marked by the growth of ice-caps on the Scottish mountains, the Lake District and the Pennines. There is little doubt that the North Sea was largely filled with ice from Scandinavia but the British ice moving south from Scotland, joined by the glaciers from the Lake District and the Pennines, hugged the low ground of the east of England, swept out over the North Sea, and successfully kept back the Scandinavian ice. Thus was formed the wholly British Great Eastern Glacier which ploughed up part of the floor of the western North Sea before impinging on the coast of Norfolk and leaving there the Contorted Drift as evidence of its work. The ice stream of the Yorkshire Coast (which deposited the Lower Purple Boulder Clay) does not appear to have over-ridden the Lincolnshire Wolds. "On the west of this escarpment the Great Chalky Boulder Clay ice, augmented by the sheets which had flowed down the Yorkshire Plain (together with Lake District ice which had come over Stainmore) travelled up the valley of the Trent and down that of the Witham, fanning out across the low ground of the eastern Midlands. Part of the sheet, which crossed the Fen district, spread eastwards and southwards over East Anglia, reaching to Finchley in North London .... The ice which had descended eastwards from the Pennines seems only to have been sufficiently powerful to travel southward side by side with the Great Chalky Boulder Clay ice and thus to have been elbowed into the Avon Valley. At the same time ice appears to have advanced from the North Sea in a south-easterly direction on to the

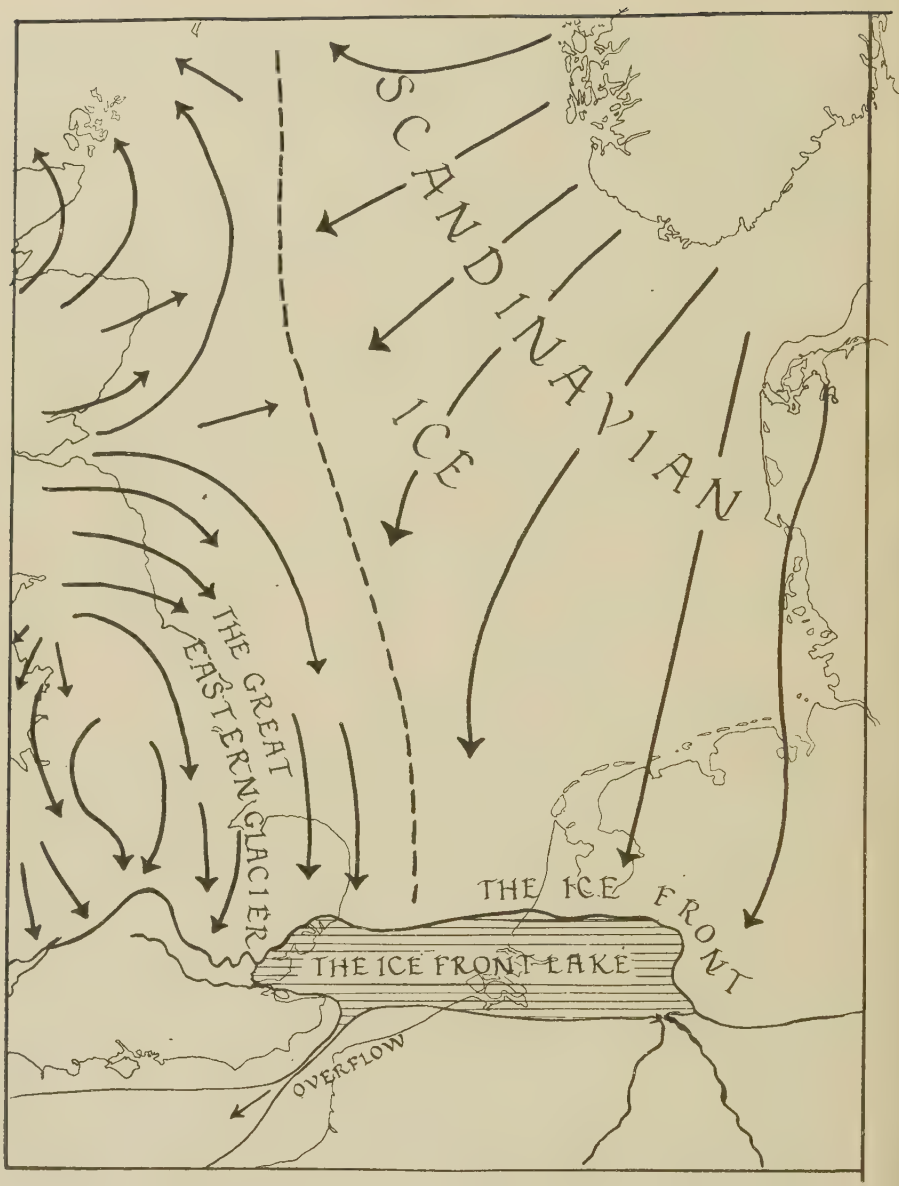

Fig. 6. The North Sea at the time of the Second British Glaciation (the period of maximum or Saxonian Glaciation of Europe).

Norfolk Coast, thereby influencing the course of the Chalky-Neocomian and Chalky-Jurassic glaciers"[19]).

This was, for Britain, the period of *maximum glaciation.* Only

[19]) P. G. H. Boswell, Pres. Address Section C, Report Brit. Assoc. Adv. Sci., York, 1932.

the south — south of a line joining the Severn and the Thames — remained outside the grip of the ice-sheets. There seems every reason to believe that it was also the period of maximum glaciation in northern Europe when the Scandinavian ice-sheet extended southwards as far as the mountains of Saxony, the Harz, Thuringia and the Carpathians. Because of its extent southwards to Saxony this was called the Saxonian or Great Glaciation by James Geikie. The term 'Saxonian' has been adopted by several geologists since, notably by Gignoux[20]), and seems safer than to assume a correlation with the Riss Glaciation of the Alps. The southern front of the ice stretched from Essex across the southern North Sea to Holland, the northern half of which was within the ice front. There seems no alternative to the view that the northern outlet for the waters of both the Thames and Rhine systems was blocked, more especially as the North Sea ice front must have 'grounded' on the Haisborough-Terschelling Rise where the North Sea to-day is only 25 to 30 m. deep. Thus the extreme south of the present North Sea Basin must have been occupied by a typical glacial lake, blocked by the ice on the north, and receiving the waters of the Thames and Rhine. This 'ponding back' of the waters was suggested long ago by Clement Reid[21]), and urged by the writer[22]), and has been accepted by the Dutch Geologist Faber[23]) amongst many others. What happened then is exactly comparable to that which happened in glacial Lake Pickering in Yorkshire and in many other well-known cases[24]). The water in the ice-front lake rose until a new escape was found. That escape was the existing valley of a Pliocene river[25]) in what is now the Straits of Dover. So the lake drained southwards to the English Channel, widening and lowering the valley which was later to form the Straits of Dover. The recent work of Baak[26]) has, from a new and comprehensive study of the sediments of the North Sea, confirmed that the Rhine thus drained southwards.

The retreat of the glaciers ushered in the very important second interglacial period of Boswell and other British geologists. The mingling of the Rhine and Thames waters permitted the spread of the temperate freshwater molluscan fauna characterized by *Corbicula fluminalis* (now restricted to the Nile and other warm rivers). Man returned to live on the river terraces and to shape Acheulian implements. These, like *Corbicula fluminalis* are associated with the 100 ft. Terrace of the Lower Thames Valley. Acheulian man was a big game hunter and he had the warm southern fauna of *Elephas antiquus, Hippopotamus* and *Rhinoceros leptorhinus* with which to contend.

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[20]) M. Gignoux, Géologie Stratigraphique 1926; 2nd Ed. 1936.
[21]) See, *inter alia*, 'Submerged Forests' Cambridge 1913, p. 67.
[22]) L. D. Stamp, Geog. Jour., LXXX, 1927 p. 386-390.
[23]) F. J. Faber. Geologie van Nederland 1933.
[24]) See the map in 'The Pennines', British Regional Geology, H. M. S. O. 1936.
[25]) Named by the writer the River Lobourg, from the 'Creux de Lobourg' now occupying this position in the floor of the Straits of Dover.
[26]) J. A. Baak, Regional Petrography of the Southern North Sea, Wageningen, 1936.

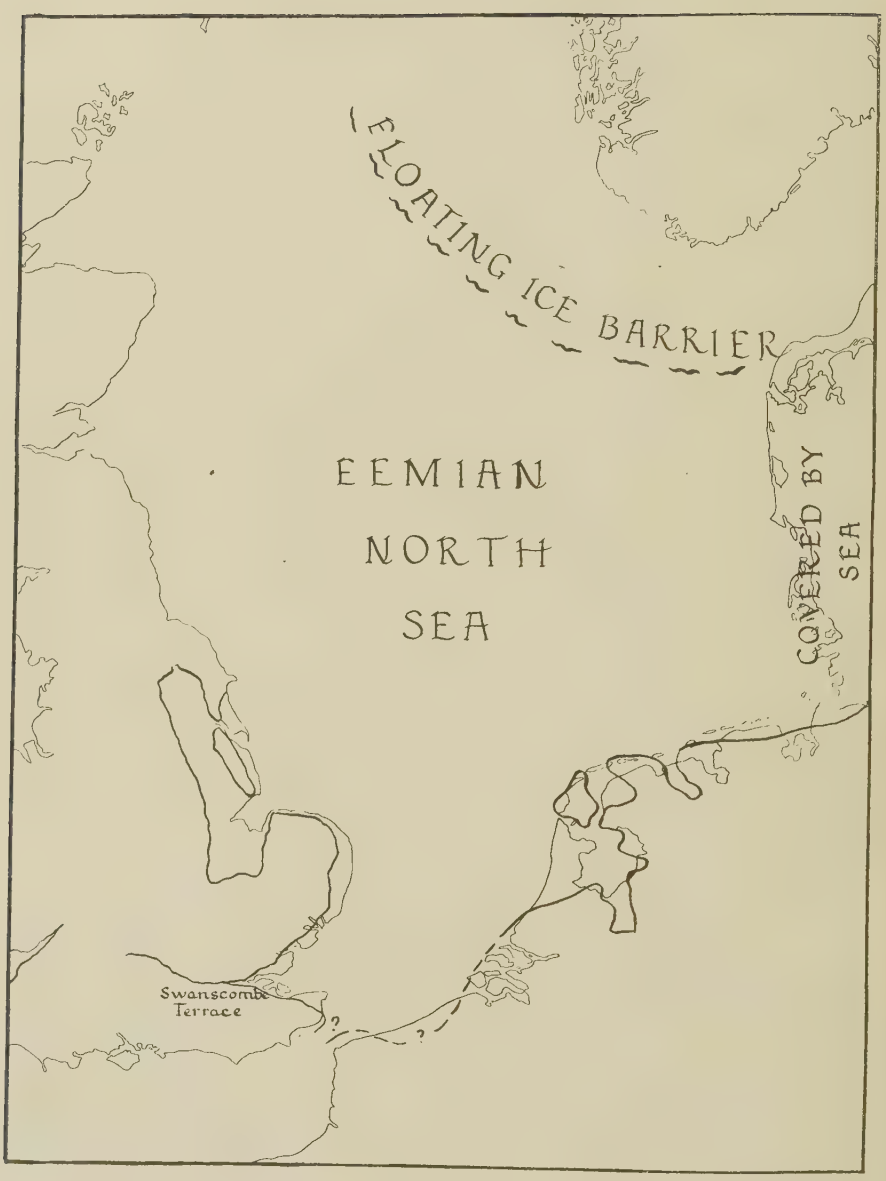

Fig. 7. The Eemian North Sea (at the time of the Second British Interglacial Period).

The retreat of the ice from Holland was accompanied or followed by a very marked marine transgression — the Eemian[27]). The Southern North Sea extended far over Holland and Denmark and the Eemian deposits, resting directly on boulder clay or outwash gravels, contain

[27]) The River Eem, south of the Zuyder Zee.

such warm water marine molluscs as *Tapes senescens* and *Bittium reticulatum* but also *Cyprina islandica*. In Holland these beds occur now at a height of 100 feet (35 m.) which is consistent with the level of the 100 ft. (Swanscombe) Terrace of the Lower Thames and with the position of the *Corcibula* gravels of East Anglia[28]).

It is not possible to say how the Eemian marine fauna reached

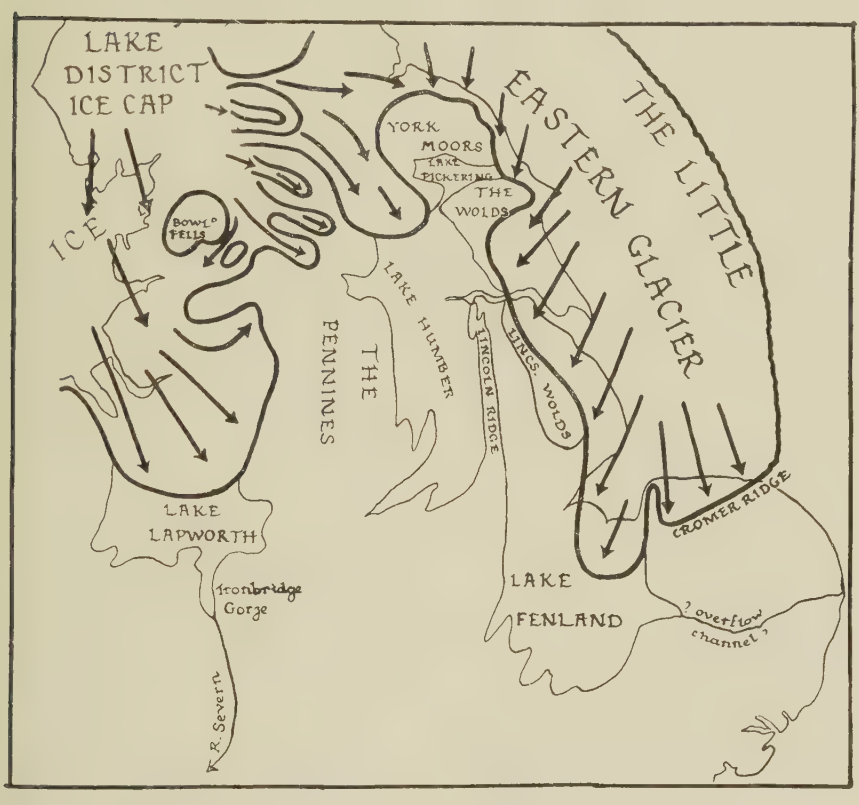

Fig. 8. Eastern England towards the close of the Third British Glaciation (after Raistrick and others).

Holland and Denmark. It *may* have come *via* the North Sea but its character suggests the temporary submergence of the Straits of Dover (after the warm land and freshwater fauna had reached Britain).

The Third British Glaciation — the advance of the Little Eastern Glacier.

Several interesting changes are to be noticed towards the end of the second interglacial period. Acheulian man gave place to Mousterian man and the climate became sufficiently cold to change rain washes

[28] For the classification of Belgian deposits see A. Rutot, Bull. Soc. Belge Géol. XXIX, 1919, pp. 31-42; pp. 151-196.

from hill slopes in southern England to movements of frozen sludge which have left the Combe Rock and trail.

In England the Third Glaciation was marked by a movement of ice from the Southern Uplands of Scotland and the Lake District across the Irish Sea to the Cheshire Plain and from the Lake District across Stainmore to the Tees Valley. In East Anglia the 'Little Eastern Glacier' invaded the north of Norfolk and the famous Cromer Ridge is probably the terminal moraine of this glacier. Elsewhere the deposits left by this Third Glaciation form what was long known as the Newer Drift.

On the eastern side of the North Sea, the ice no longer stretched far over the water. But the ice still covered the whole of Denmark, there frontal or terminal moraines stretch between Stade and Bremerhaven being found along the *right* bank of the Weser and the Aller, passing through Magdeburg, Spremberg to Plock on the Vistula. Behind this frontal or terminal moraine[29]), that is to the north and north-east, there is a succession of moraines which mark stages in the retreat of the ice. The rivers of Germany, flowing from Central Europe, were unable to make their way to the still ice-covered Baltic as they do to-day, and so flowed *parallel* to the front of the ice, receiving from its melting large volumes of water, and so towards the North Sea. These old marginal valleys, in large part unoccupied by rivers at the present day, form the well-known *urstromtäler* of German geologists.

The Period after the Third British Glaciation.

Whatever may be the reason, there seems little doubt that the area at present covered by the southern North Sea was at this time a low-lying plain with quietly meandering rivers. At first it had an Arctic or Tundra climate and may be compared with the low-lying plains of northern Siberia. *The present floor of the North Sea is essentially the buried landscape of this period.* Except in the south, it would seem that the sediments of the North Sea floor are those which covered this late Pleistocene land-surface though partly resorted by current action. Special interest therefore attaches to the researches of J. A. Baak, published in his 'Regional Petrology of the Southern North Sea' (1936) in which he incorporated the results of previous work on North Sea sediments. Essentially he finds the north-eastern two-thirds of the sea-floor covered with glacial and fluvioglacial deposits of Scandinavian origin, together with resorted Pliocene and probably with silt or other sediments from German rivers. The north-western third is similar material mainly of English-Scottish origin. Between the mouth of the Thames and the mouth of the Rhine is an area covered by sediments whose mineral composition suggests that they were deposited by the Rhine. Only along the Belgian-Dutch coasts has there been extensive *later* resorting of materials. This is Baak's view, but

[29]) This terminal moraine may be later than the Third British Glaciation as suggested by the table given above.

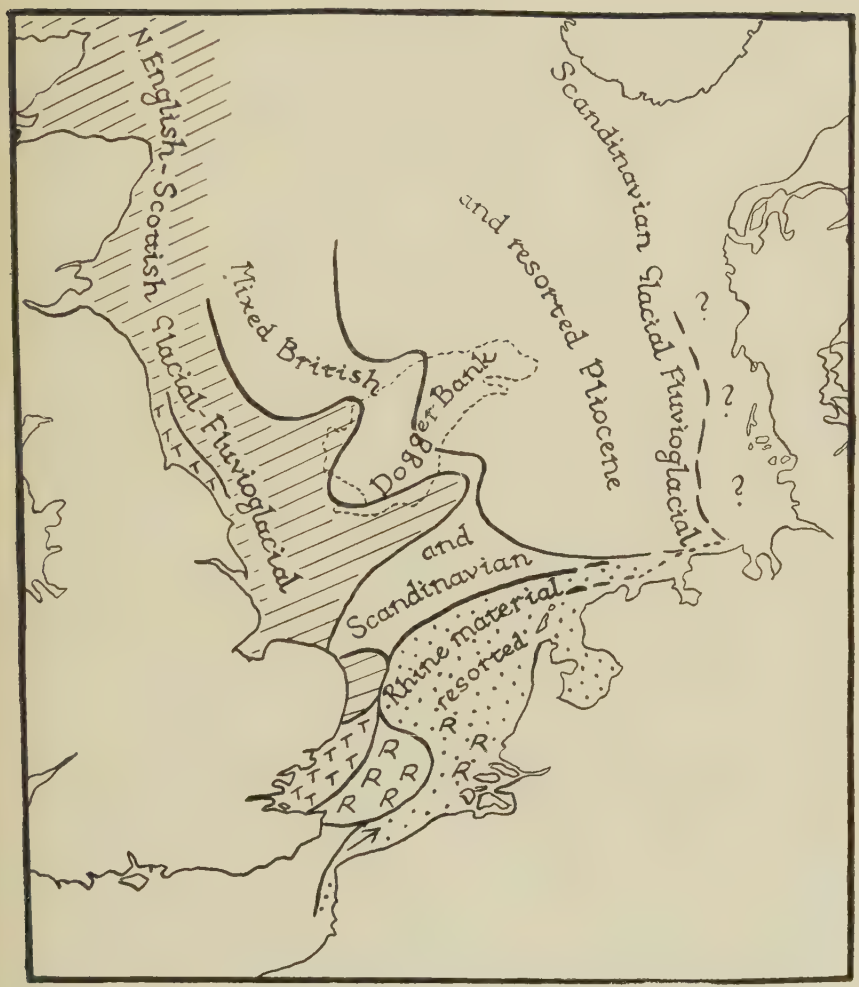

Fig. 9. The Petrographic provinces of the North Sea according to J. A. Baak.

it does not entirely accord with the famous researches of J. O. Borley (The Marine Deposits of the Southern North Sea. Min. of Agric. and Fisheries, Fishery Investigations, Ser. II, Vol. IV, No. 6, 1923). Borley found that the existing distribution of material is largely the result of selective transport by current aided by wave action, and that wave action was operative down to at least 120 feet (20 fathoms). Coarse material occurs where current action is such as to prevent the accumulation of silt and finer materials. The North Sea is divided, however, into an 'English Channel' and a 'German Bight', on either side of the Dogger Bank. Borley shows that there is little transport of material *across* the Bank from east to west and thus little mixing of the material of the two provinces determined by

Baak. For details of the conditions in the German Bight reference should be made to Otto Pratje's comprehensive work[30]).

The extensive and rapid movement of material along and near the coasts of the North Sea is, of course, well known[31]).

The late Pleistocene land-surface of the North Sea has long been postulated by geologists. Various authors such as Jukes-Browne[32]) (1888), Sir Halford Mackinder[33]) (1902), Clement Reid[34]) (1913) have published maps showing the Humber — Little Ouse — Thames systems joining up with those of the Rhine and Elbe and flowing across this plain to the sea far in the north. J. W. Gregory[35]), mainly for zoological reasons, is alone in believing that the Thames and the Scheldt joined to flow southwards (through a valley occupying the centre of the Straits of Dover) whilst the Rhine (which he shows passing through the Zuyder Zee) joined the rivers from the Wash and Humber and flowed northwards. Baak, to explain the distribution of certain heavy minerals in the North Sea and sediments, believes the Rhine joined the Thames and flowed southwards.

As the ice (which most Continental geologists regard as ice of the same age as the Würm glaciation of the Alps) retreated, the North Sea tundra plains with their *Elephas primigenius, Rangifer tarandus* and other Arctic animals enjoyed an amelioration of climate. The vegetation began to change gradually from that of an 'Arctic prairie' to forest with *Pinus sylvestris* and *Betula.* Sea-level may have been as much as 150 or 200 feet (50—60 m.) below its present level, (Tesch and Schutte). The forests of this period or slightly later are preserved to us as the famous 'submerged forests' found round the shores of Britain. What is now the Dogger Bank seems to have been occupied by a tract of fen in which fenland peat accumulated. Fragments of this peat-bed are frequently dredged and are known to the fishermen as 'morlog'. The peat consists of species common in the English Fens of to-day, but with such species as *Betula nana* indicating a distinctly colder climate. The Dogger Fen may have been bordered with sand-dunes, if the evidence of the beetles associated with the peat can be taken as conclusive[36]). The Dogger Bank peat occurs at a depth which suggests a greater difference of level than do the submerged forests of the English, Dutch, and German coasts where the forests occur at depths of 50 to 60 ft. below present mean sea-level, so that

[30]) Die Sedimente der Deutschen Bucht. Wissenschaftliche Meeresuntersuchungen Abt. Helgoland, Vol. 18, Nr. 6, 1931.

[31]) See *inter alia,* J. A. Steers, Scolt Head Island, Cambridge, 1935; papers by H. Muir Evans *(Mariner's Mirror,* Vols XV-XVIII, 1929-1932).

[32]) Building the British Isles, 1st edition, p. 294. See also Contemp. Review 1893 pp. 704-712.

[33]) Britain and the British Seas, p. 140-1.

[34]) Submerged Forests, p. 40.

[35]) Geogr. Journ. LXX, 1927, pp. 52-59.

[36]) For a discussion of the implications see Clement Reid, Submerged Forests, especially Chap. IV; also Essex Naturalist, XVI, pp. 51-60. On the molluscs see O. Pratje, Centralblatt f. Min., Jahrg. 1929, 56-61.

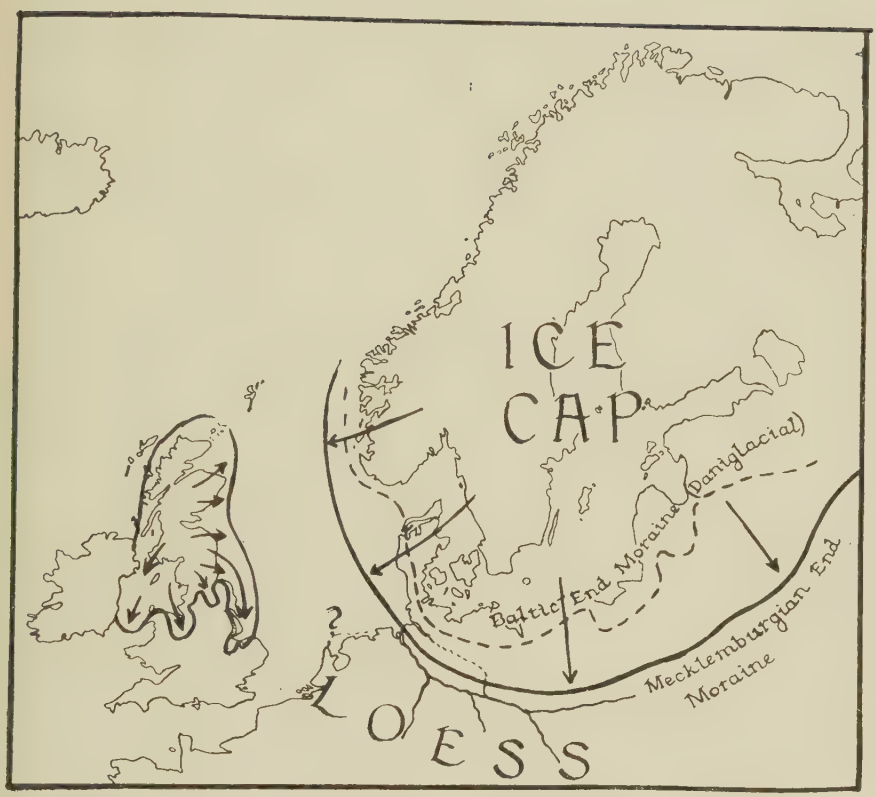

Fig. 10. North Europe showing the limits of the Mecklemburgian Glaciation, probably contemporary with the Third British Glaciation. This map also shows the position of the next stage of retreat, the Daniglacial (Baltic End Moraines). The rivers parallel to the ice front in Germany should be noted.

the land stood at least 70 ft., more probably 90 ft. (20—30 m.) above its present level. The submerged forests of Britain are mainly of oak but the flora and fauna associated are poor. Recent investigations in France, (D u b o i s) and Holland (by T e s c h and Mrs. V e r m e e r - L o u m a n) suggest that peats and submerged forest of several ages may have been confused in Britain.

The land phase of the North Sea came to an end by the steady southward advance — for the last time — of the North Sea. For most geologists this marks the end of the Pleistocene and the beginning of the Holocene — the Recent or Post-glacial period. In this sense the North Sea of to-day is essentially a recent phenomenon. B a a k points out that the renewed southern invasion of the sea from the north must have taken place along the lower ground of the North Sea Plain, leaving the higher ground of the Dogger Bank and the centre of the Harlsborough-Terschelling rise as land for a considerable period. He believes that the first connexion between the English Channel and the North Sea was made along the "Deep-Water" between the Dogger

Bank and the English coast and that a separate arm of the sea reached the Flemish-Dutch coast. He places the beginning of the 'Atlantic' period (see below) at the time when the connexion was first etablished. It is difficult to reconcile this reconstruction with Dubois' work, but it is supported in considerable measure by Borley's and Pratje's studies of the North Sea sediments, and by the investigations on the British flora by Woodhead, Erdtman and others mentioned below.

Late Glacial and Post-Glacial Chronology.

The late Glacial and Post-Glacial history of the North Sea Basin is closely allied with that of the Baltic Sea, where De Geer and his fellow workers have been able by a detailed study of the 'varved' or seasonally banded sediments, to work out a time-scale measurable in years[37]). G. Dubois[38]) working in the north of France has attempted to correlate events there with those in the Swedish area but in the correlation there are many difficulties. In the first place it must be remembered that the removal of the ice in Scandinavia led to an enormous regional uplift to the land — 700 or 800 feet — far exceeding any change of level along the British and southern shores of the North Sea. Thus the movements must have been differential and not eustatic.

Daniglacial. This period of ice-retreat from over Denmark has not been dated in years. We may presume it to have taken place during the pre-Boreal period (see below) when the North Sea Basin was occupied by tundra.

Gothiglacial. This period of ice-retreat across southern Sweden lasted from about B. C. 14,000 to B. C. 10,000. During this period the margin of the Scandinavian ice-sheet retreated across southern Sweden. Marine beds known as the Upper Senglacial were deposited in Denmark possibly from an extension of the deep waters now found in the 'Norwegian Deep', as well as Continental deposits with 'Dryas' or Tundra flora — the older Tundra flora (pre-Boreal). Dubois believes that a shallow and narrow arm of the sea occupied the Straits of Dover and stretched over Flanders, but that it was blocked by ice in winter so that mammoths and other large animals could cross to Britain, whereas in summer icebergs with erratics from Brittany drifted eastwards up the English Channel through the Straits to the Ostend Bay where marine sands (the Lower Flandrian) were being deposited. Again according to Dubois the younger limon (or loess of France) was being formed and about 10,000 B. C. there was a slightly warmer period; towards 9,000 it was again colder. The land continued to rise.

[37]) See especially G. De Geer, C. R. XI[e] Congr. Géol. Intern. Stockholm, 1910, I pp. 241-253; M. Sauramo, Fennia XLIV, 1924.

[38]) G. Dubois, Ann. Soc. Géol. du Nord, XLIX, 1924, pp. 120-130; Mem. Soc. Géol. du Nord VIII, 1924.

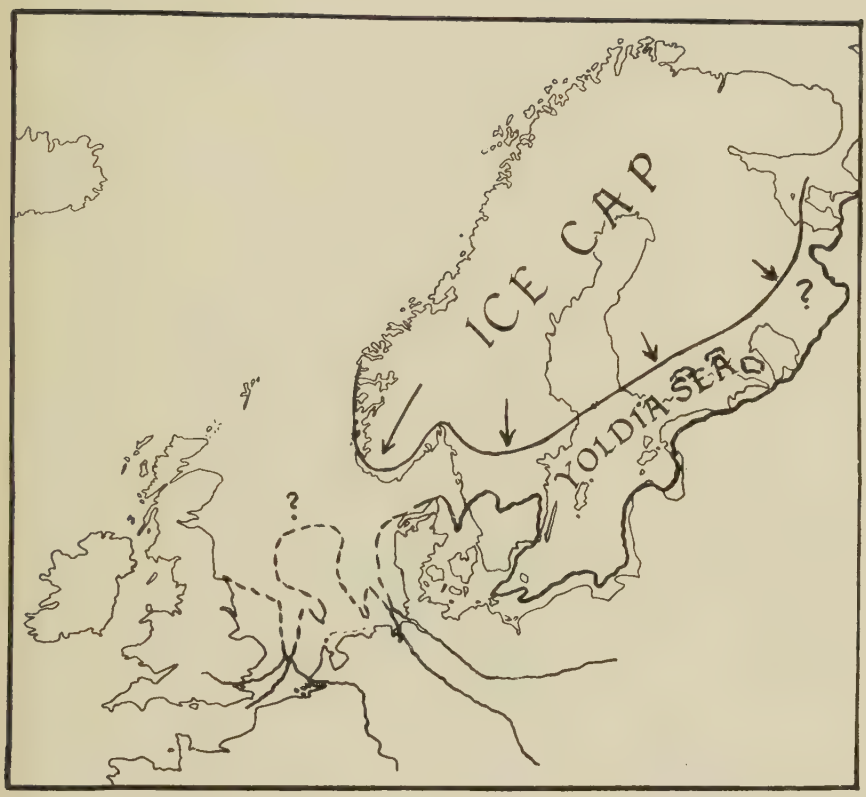

Fig. 11. Northern Europe during the Yoldia Sea Period — the beginning of the Finiglacial when the Scandinavian moraines and the Salpausselka of Finland were being formed. Ca. B. C. 9000 — 8000 (after Sauramo). The gradual emergence of the floor of the North Sea at this period is postulated.

Finiglacial[39]). This period lasted from about 8,500 B. C. to 6,500 B. C. In the early part of this period the climate was distinctly colder than at present, giving rise to the younger Tundra or Dryas flora. There was a pause in the ice retreat and the famous end moraines of Sweden and Finland (Salpausselka) were formed. In northern France, (Dubois), estuarine deposits yielding *Elephas primigenius* were laid down in the Calais Bay.

About 8,000 B. C. the Finiglacial Retreat commenced. A sea of Arctic temperatures (the *Yoldia* Sea) occupied the Baltic and may have been linked with the White Sea. The mammoth left north-western Europe, the reindeer and the other Arctic mammals left the southern shores of the North Sea and retreated northwards.

[39]) J. K. Charlesworth considers the last Highland glaciation was contemporary with the Finiglacial. Proc. Roy. Irish Acad. XL, B, 1931, pp. 27-83.

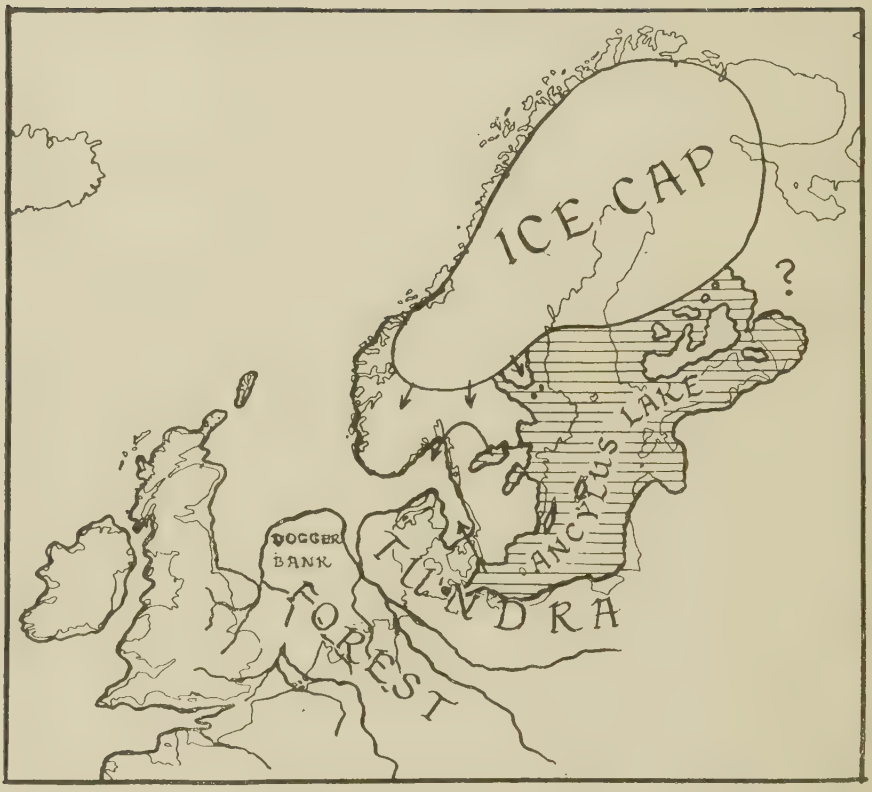

Fig. 12. Northern Europe during the Ancylus Lake Period (late Finiglacial, ca. 7500 B. C.) — the Boreal or Submerged Forest Period in Britain (after P r a t j e and S a u r a m o).

Later, the climatic conditions improved and, possibly as a result of the diminution of the weight of ice, Denmark rose and the Baltic was cut off from the North Sea and formed a lake (*Ancylus* Lake). Northern Denmark was occupied by tundra and became habitable by man, and the forest belt commenced to invade southern Denmark. According to D u b o i s, along the northern French shores of the North Sea, sea-level stood about 15 or 16 m. above the present, and men with finely chipped flint knives (Azilian) lived in Western Europe.

P o s t g l a c i a l. The postglacial period of Swedish geologists commences about 6,500 B. C. The Scandinavian Ice sheet was reduced to two masses and at first remained stationary, as did the sea-level along the southern shores of the North Sea. The Calais Bay was an area of peat formation. D u b o i s believes that the Straits were open, but shallow and narrow.

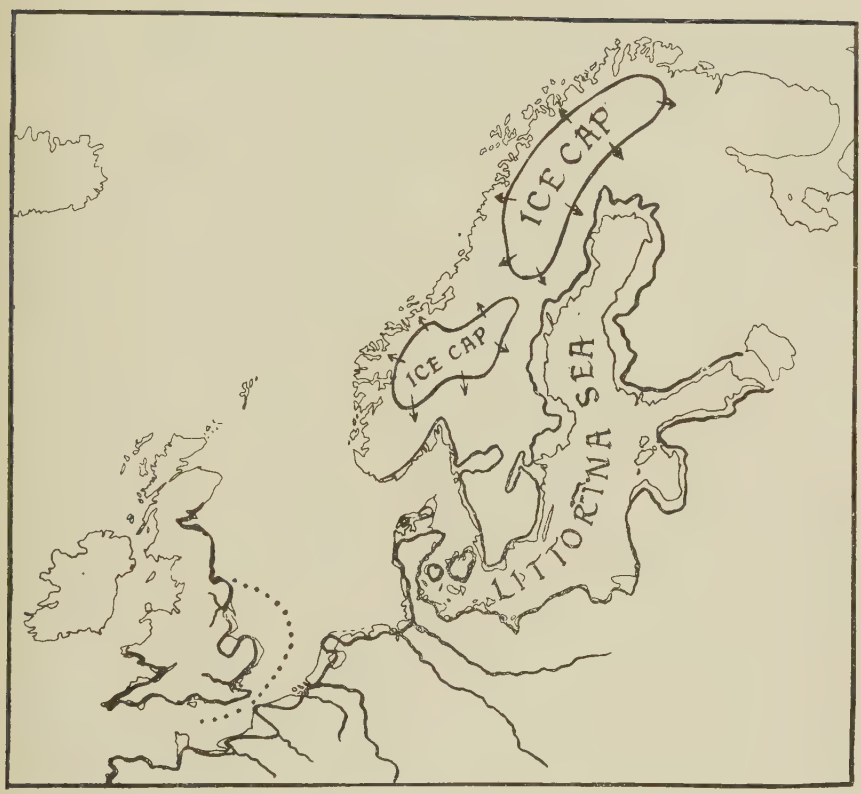

Fig. 13. Northern Europe during the littorina Sea Period (Atlantic Period ca. 4000 B. C.). This was the period of the 25'Neolithic Raised Beach of Britain and the Middle Flandrian Transgression in Northern France. The line of dots shows the probable line of the first sea connexion between the North Sea and the English Channel (after Sauramo, Pratje and others).

About 6,000 B. C. came the final retreat of the Scandinavian Ice sheet. This was accompanied by a remarkable transgression of the waters of the North Sea. The North Sea invaded the Baltic (as the *Littorina* Sea); beds with *Tapes* were laid down over Denmark and the Flemish plain was also invaded as was the Plain of Picardy (transgression of the Middle Flandrian) and the Straits of Dover assumed something of their present character, so that the movement of a land fauna between Britain and the Continent ceased. In northern France the sea was about 12 or 10 m. above the present level and the rivers, thus rendered sluggish, became areas of marsh and of peat formation. In Britain this period of marine transgression is marked by the well known Neolithic (25 foot) Raised Beach, about 4,000 B. C. Neolithic man was living in Denmark and building his "Køkkenmøddings". Britain was definitely and finally cut off from the Continent.

During this period the sands and other sediments which had been transported from the southern North Sea to the English Channel by the overflow channel of the old Glacial Lake and possibly by the Rhine, were swept back by the strong tidal current. There was a strong tidal scouring and the Straits were rapidly deepened (Lobourg trough) and widened. This was during the Atlantic period (see below) and the opening of the Straits of Dover to the influence of warm waters from the North Atlantic may have been largely responsible for the change in the character of the climate. From the projecting Cape Gris Nez (west of Calais) a sand-bar grew out and behind it accumulated clays and silts. Similar sand-bars to the north-east form the "Oude Duinlandschap" (Old Dune Formation) of Holland and the silt behind the "Oude Zeeklei", (Old Sea Clay). Later tidal marsh or swamp and heath vegetation spread over the sea clay (in the sub-Boreal period) and it is believed that the Romans knew the Dutch coastal area as a belt of swamps bounded on the sea-ward side by the Old Dune Formation[40]). With the opening of the connexion between England and the Dogger Bank, there would be initiated the system of tidal currents which characterize the area to-day[41]). It was not, therefore, until this period that the resorting of the materials on the floor of the North Sea, shown by Borley's investigations, was begun and, at the same time, the whole present-day trends in coast erosion and coastal accumulation.

De Geer's chronological scale was based on the actual counting of the seasonal layers or varves of the post-glacial sediments of Sweden. It is an absolute scale of years and may be linked exactly with the stages of ice-retreat in Scandinavia and with the evolution of the Baltic Sea. An attempt, using the work of A. Blyatt[42]) by R. Sernander[43]) was made to draw up a scheme of post-glacial chronology. This work in Sweden can be linked with De Geer's scale. The correlation given by Pratje[44]) for *southern Sweden* and the neighbouring parts of the Baltic is as follows:—

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[40]) On the effect of currents off the Belgian Coast see C. J. van Mierlo, Bull. Soc. belge Géol. XIII, 1899 pp. 219-265.

[41]) See J. O. Borley, *op. cit. sup.*, O. Pratje, *op. cit. sup.*, also Atlas of Tidal Streams of the North Sea (Hydrographic Office of the Admirality, 1899), C. H. Brown, Report on the Deep Currents of the North Sea, (North Sea Fisheries Invest. Com. 4th Report, 1909. *Ibid* 2nd Report, Fishery Board for Scotland, 1914.)

[42]) Essay on the Norwegian Flora, Kristiania 1881; Wechsel continentaler und insularer Klimate nach der Eiszeit. Naturf. 1881; Bot. Jahrb. Pflanzengeogr. II.

[43]) The Swedish Peat Bogs as evidence of post-glacial changes of Climate C. R. Cong. géol. intern. Stockholm, 1910, Vol. II.

[44]) O. Pratje Die Tierwelt der Nord- und Ostsee: Einführung in die Geologie der Nord- und Ostsee, 1931.

	De Geer	Climatic Periods	Baltic Sea Stages	Cultural Periods
		Subatlantic	*Mya* Sea	Historic Times Iron Age
BC 1000		Sub-Boreal	*Lymnaea* Lake	Bronze Age
BC 2000	Post-			
BC 3000	Glacial	Atlantic	*Littorina* Sea	Younger neolithic
BC 4000				
BC 5000		Boreal		Older neolithic
BC 6000			*Ancylus* Lake	Oldest neolithic
BC 7000	Fini-	Subarctic		
BC 8000	Glacial	Arctic	*Yoldia* Sea Ice-covered	
BC 9000	Gothi-			
BC 10000	Glacial			
BC 15000				
BC 18000	Dani- Glacial			

The Arctic period is regarded by Pratje as having a July temperature increasing from 6°C. (43°F.) to 9°C. (48°F.) — and is essentially the climate of the tundra.

The Subartic period with July temperatures from 10°C. (50°F.) to 12°C. (54°F.) makes possible the growth of 'Arctic prairies' and Arctic trees such as *Betula nana.*

The Boreal period had a climate of continental type with short, hot, rather dry summers (July 17°C. or 63°F.) and long cold winters, and one which favoured the 'taïga' type of forest — with *Pinus Abies* and *Betula.*

The Atlantic period had a climate more marked by oceanic characteristics, not greatly different from that of Britain to-day, but warmer, i. e., resembling that of present-day Denmark or warmer, with a July temperature 18—18.5°C. (64—65°F.) and one which favoured broad-leaved, deciduous forests.

The Sub-Boreal period had a lower July temperature (17°C. or 63°F.) and was damper and cooler.

The Subatlantic period, lasting to the present day has relatively cool, short summers (16°C. or 61°F. in July).

It is important to note that these temperatures and periods refer to *southern Sweden.* It is probable that the same general sequence of climatic periods (with local modifications) followed the ice age in Britain, but what seems to the writer a fatal mistake is to regard them as synchronous in Britain and southern Sweden as Woodhead[45])

[45]) T. W. Woodhead, Jour. Ecology, XVII, 1929, pp. 1-34; Tolson Memorial Museum Handbook VIII, Empire Forestry Journal, VII, 1928.

Fig. 14. The North Sea of to-day, showing the positions (in black) over 50 m. and which indicate the probable Channel of early Atlantic connexion between the North Sea and the English Channel.

black — over 50 m.; hatched — 50-20 m.; white — under 20 m.

has done. In view of the position of the British Isles, nearer the Atlantic, we may more rightly regard the corresponding climatic period as occurring considerably *earlier* than in Sweden and Denmark. With this reservation we may use the very valuable detailed work of W o o d h e a d on the history of the vegetation of Britain (especially his work on the Southern Pennines) and the results obtained by G. E r d t m a n by his now famous methods of pollen analysis of peats. In the late glacial period (which W o o d h e a d calls 'Würm' — presumably the third British glaciation of the scheme given above), it is probable that the high ground of the Pennines remained as a 'nunatak' above the ice and had a tundra flora with common moorland species. As the following Arctic period merged into the sub-Arctic, *Betula* appears and in the Boreal period there were forests on the Pennines — mainly of birch, but with hazel, alder and oak, later with occasional pine[46]) and elm. The ground flora was heath *(Calluna)* and during this 'warm dry Continental period' Tardenois man lived in the area. During this period the Pennine forest reached its maximum: with the coming of the damper, cooler Atlantic period the forest began to degenerate. W o o d h e a d agrees that at this time Britain became cut off from the Continent; it is the writer's belief, as noted above, that the severing of the land connexion and the new circulation of water round the islands actually *caused* the climatic change, probably considerably earlier than in Denmark and Sweden. By a micro-analysis of the 'moorlog' of the Dogger Bank, E r d t m a n[47]) assigns an early Boreal age to it — which is consistent with the sequence of events already outlined. In the Pennines *Eriophorum* (Cotton grass) replaced *Calluna-Betula* in Atlantic times and the associated human tools are Neolithic. In the succeeding sub-Boreal time *Calluna* returned, with beech and fir *(Abies)* and Bronze Age tools are found. The final sub-Atlantic period brings the sequence to the Iron Age and the present day.

V. Conclusion.

Any attempt to trace the geographical evolution of the North Sea Basin from Miocene times to the present day is to be regarded merely as an attempt based on the state of knowledge at the moment. Perhaps a dangerously positive tone has been adopted; it is merely that the erection of an edifice with some definition does at least afford a target for others to attack.

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[46]) Elsewhere the post-Glacial maximum for pine was reached.
[47]) Essex Naturalist XXI, 1925, pp. 107-112.

Salient Features of the Hydrography of the Northern North Sea and the Faroe-Shetland Channel in 1935.

By

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THE hydrography of the northern North Sea and the Faroe-Shetland Channel in 1935 presented some peculiar features which are the subject of this preliminary notice.

The most significant factor in northern North Sea hydrography is always the oceanic influence which proceeds from the north-eastern Atlantic Ocean by way of the Faroe-Shetland Channel. At all events the major hydrographic variations in the northern North Sea are more or less concomitant with the seasonal and annual variations in the strength and volume of this oceanic impulse. Estimation of the intensity of the Atlantic incursion is therefore of prime importance to northern North Sea hydrography. On account of the general insufficiency of data, this estimation is usually made by inference from the actual temperatures and especially the salinities recorded, and from their vertical and horizontal distributions.

The most reliable cross-section of the Atlantic current, from which to gauge its strength, is that which is to be obtained in the Faroe-Shetland Channel, between Shetland and Faroe. Following upon the close connexion which, early in the history of the hydrographical investigation of these regions, was shown to exist between the Faroe-Shetland Channel and the northern North Sea, the apparent intensity of the oceanic stream in the former region has in the past been taken as evidence of the intensity of its influx into the North Sea. Based on a misconception, however, the connexion between the two regions has formerly been believed to be more direct than is actually the case.

A special study of temperature and salinity distributions in the regions concerned[1]) has established the indications of certain drift-bottle results to the effect that the invasion of the northern North Sea by Atlantic water takes place almost entirely through the uninterrupted

[1]) J. B. Tait: Surface Drift-Bottle Results in relation to Temperature, Salinity and Density distributions in the northern North Sea. Cons. Int. pour l'Explor. de la Mer., Rapp. et Proc.-Verb., LXXXIX, 1934, III, No. 8.

opening between Shetland and Norway, and not to any appreciable extent, if at all, through the passages between Shetland and the mainland of Scotland, as has hitherto been supposed. This is an important finding, for it means that, before reaching the North Sea from the Faroe-Shetland Channel, the Atlantic current encroaches upon another hydrographical region, namely, the southern Norwegian Sea where, as seems to have occurred in 1935, it may be subject to modifying influences. Hence, an estimate of its strength in the Faroe-Shetland Channel may not always be a safe guide to its effect upon the North Sea, although in relation to events in the latter region it will always be an advantage to know something of conditions in the former.

At the end of 1934, in summarizing the Scottish hydrographical work for that year, the prognostication was made that, in the following year, the incidence of spring conditions in the northern North Sea would in all probability be delayed. By this was meant that the oceanic influence, which usually from December onwards increases rapidly towards maximum intensity in March or April, would, in 1935, not attain this maximum until later in the year. Despite an indication from salinities observed in March in the neighbourhood of Shetland that the Atlantic stream was then flowing fairly strongly, the results of surface drift-bottle liberations carried out between March and May 1935 tend to the conclusion that, so far as concerns the northern North Sea, it was not until June that the maximum intensity of the Atlantic impulse for the year was registered.

The above anticipation of the early events of 1935 was also based upon the results of surface drift-bottle liberations carried out in the months of November and December 1934. These results showed that a strong northward drift was then running along the entire length of the Scottish east coast, embracing the waters out at least to the prime meridian. The evidence is that this northward drift endured until the end of January 1935, if not longer, that is, well into the period when the southward urge, due to oceanic influence, ought to have been increasing in strength. The oceanic incursion of 1935 had obviously first to overcome this reverse movement on the western side of the North Sea.

By the month of April, the northmost reaches of the North Sea and the waters for some distance southward a little to the west of zero meridian, were distinctly oceanic in character. Temperatures and salinities were, in fact, above the average values in these regions during this month. But, on the other hand, the intensity of the incursion cannot have been so strong as these observations suggest, for in the following month, the effect had not yet reached the middle North Sea area south of about latitude 58° N, where the chief physical characteristics of the upper waters especially were appreciably below normal for the time of the year.

Towards June, when increased oceanic activity was evident in the northern area, a further indication of the drift-bottle results already referred to was that the pulsation was not a particularly strong one,

less so than the actual salinities recorded would lead one to deduce. Its influence continued to be confined very largely to the north-western part of the North Sea. Even two months later, when it was anticipated that Atlantic water would be found to have extended its influence considerably southwards, very little of it appeared below latitude 58° N.

These circumstances are the more surprising when it is known that, in June, water of very high salinity — up to 35.50 ‰ — indicating a powerful Atlantic current directed towards the Faroe-Shetland Channel, was found in the region of the Wyville Thomson Ridge. On a hydrographic section between the Butt of Lewis and Faroe Bank, water of scarcely less than 35.35 ‰ salinity occupied all depths along the entire section, while the cross-sectional area of 35.40 ‰ water, and over, was almost equal to that found on the same section at practically the same period of 1933 which was a "peak" year as regards the intensity of the Atlantic current in the Faroe-Shetland Channel and also in respect of its influence upon the northern North Sea[1]).

A most fortunate drift-bottle result gave the first indication of the reason for this influence being so much less in 1935. A bottle set adrift on 26th May 1935 near the island of North Rona, which lies some 40 miles in a north-easterly direction from the Butt of Lewis and 25 miles within the 100-fathom line, was most surprisingly recovered on the Island of Fuglö in the Faroe group, 43 days later, having apparently cut rectangularly across the Atlantic stream, if we assume this to have been heading as usual north-eastwards through the Faroe-Shetland Channel. The true explanation of this and certain other drift-bottle results, especially from the June liberations along the line of stations from Butt of Lewis to Faroe Bank, seems to be that a very large part of the Atlantic stream itself was diverted in a north to north-westerly direction soon after it reached the Wyville Thomson Ridge, passing thence towards Faroe Bank and the west side of Faroe.

This deduction is not discounted by the fact that, in the same month of June 1935, the whole region between Faroe and Shetland, in the uppermost 250 metres at least, was flooded with Atlantic water of scarcely less salinity than 35.30 ‰. There is reason to believe that this flooding was caused by a strong resistance to the further progress northwards of the great Atlantic drift, and here again, the apparent histories of certain drift-bottles, or rather drift-buoys, in conjunction with other factors, probably furnish the explanation of this phenomenon which affected the flow of oceanic water from the Faroe-Shetland Channel into the northern North Sea by way of the north of Shetland.

In Bulletins Nos. 7 and 9 (1935) of the Arctic Institute, accounts are given of the extraordinarily rapid transport of no less than eleven drift-buoys from the northmost part of the Kara Sea, where they were liberated during August 1934, to the north-west coast of Norway,

[1]) J. B. Tait: Recent High Salinity Records from the Northern North Sea. Cons. Int. pour l'Explor. de la Mer. Rapp. et Proc.-Verb., XCIV, 1935, III, No. 3.

where they were recovered between the end of April and the middle of July 1935. The buoys are assumed to have "rounded Franz Joseph Land and Spitzbergen from the north and to have got into the East Greenland current, from where they were carried by the Jan Mayen current to the Lofoten Islands." The rapidity of their passages over this route is taken to denote "an intensified clearing of the Polar Basin from ice, towards the end of 1934 and the beginning of 1935, through the gate between Greenland and Spitzbergen." It is mentioned also that "the atmospheric conditions observed in the winter of 1934 and spring of 1935 in the sub-Atlantic portion of the Arctic were such as to increase the activity of the East Greenland current."The same no doubt held in regard to the East Icelandic Polar current, with the result that its influence was felt much nearer to Faroe and perhaps Shetland than is usually the case. In these conditions, commencing with an increased Polar activity in the summer of 1934, appears to lie the reason for the evident stemming of the Atlantic current in the Faroe-Shetland Channel during the summer of 1935, allowing only a restricted portion of it to pass round the north of Shetland into the North Sea.

Not only did conditions in the southern Norwegian Sea during 1935 retard the advance of the Atlantic stream beyond the Faroe-Shetland Channel, but they appear also to have hindered the usual strong outflow from the North Sea along the Norwegian coast. Of the large numbers of surface drift-bottles liberated annually in the northern and middle areas of the North Sea, by far the greatest proportion of returns comes as a rule from northerly Norwegian latitudes, and there seems generally to be no particular period of the year when such strandings may not be expected. In 1935, only isolated drifters among those liberated during the months of March, April and May, attained to the higher latitudes of Norway and the few which did so were not recovered until after the middle of October. From the later North Sea liberations of the year — August to November — the Norwegian coast recoveries north of latitude 62° N. took place mostly in the early months of 1936.

Another circumstance pointing to the "closure" of the North Sea in the north was the extraordinary concentration of recoveries which took place in the months of September, October and November 1935 on the North Sea section of the Norwegian coast, between about latitudes 59° N. and 61° N. These belonged to the liberations of every month from March to August inclusive. This particular coastline is not one from which many Scottish bottles are normally returned. Moreover, in a hydrographic year such as 1935 appears to have been, when the southward urge in the North Sea due to oceanic influences is distinctly weak, the expectation in regard to drift-bottle recoveries towards the end of the year, when this oceanic force is approaching a minimum, is that these will mostly occur without the North Sea.

Thus we have in the hydrography of the Faroe-Shetland Channel and the northern North Sea during 1935 a number of apparently

contradictory features, illustrating the complexity of the hydrographic problem in these regions. It is obvious that, in the study of the physical conditions of the northern North Sea, one must take into account not only the great oceanic stream coursing through the Faroe-Shetland Channel and the lesser influence proceeding from Baltic regions (which has not been dealt with specifically in this report), but also the trend of contemporary hydrographic events in the far north, in so far as these may affect conditions in the southern Norwegian Sea adjacent both to the Faroe-Shetland Channel and the North Sea. A point, moreover, which is to be noted in conclusion is the value, towards hydrographic interpretations, of surface drift-bottle results, either in extension or in modification of the inferences which may be drawn from temperature and salinity distributions.

Variations in Temperature and Salinity in the Northern North Sea.

By

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IN *Rapports et Procès-Verbaux des Réunions*, Vol. LXXXIX and XCIII, 3ème partie, two reports appeared by J. B. T a i t, dealing with the hydrographic conditions in the Northern North Sea[1]). These reports have led me to consider the results of the Dutch hydrographic observations[2]), carried out by Dr. J. J. T e s c h on H. M. S. "Nautilus" during the months of June and July 1931—1935 in the same region.

From figures 1—5, which show the positions of the stations, it appears that sufficient observations are available to compare the hydrographic conditions in a vertical section between Shetland and Norway in the years 1931, 1933, 1934 and 1935. The same holds good for horizontal layers, at the surface and at deeper levels in the region to the south of the above section. The station-numbers are in accordance with those printed in the Bulletins Hydrographiques.

Horizontal Diagrams. In the station-charts (Figs. 1, 3, 4 and 5) surface isohalines have been drawn for the years 1931, 1933, 1934 and 1935. These charts show the usual region of Atlantic water east of Shetland[3]).

1931. The isohalines for 35.3 $^0/_{00}$ and 35.4 $^0/_{00}$ show that the surface salinity is in excess of the normal value. At a depth of 50 m. the salinity is higher than at the surface and an isolated area is shown in

[1]) (a) Surface Drift-Bottle Results in Relation to Temperature, Salinity and Density-Distribution in the Northern North Sea, Vol. 89.
(b) Recent High Salinity Records from the Northern North Sea, Vol. 94.

[2]) Salinities were determined at the "Rijksinstituut voor Chemisch, Microbiologisch en Hydrografisch Visscherij-onderzoek", den Helder, (Director, Dr. F. L i e b e r t).

[3]) Atlas de Température et Salinité moyenne de l'eau de surface de la Mer du Nord et de la Manche, publié par le Bureau du Conseil, 1933.

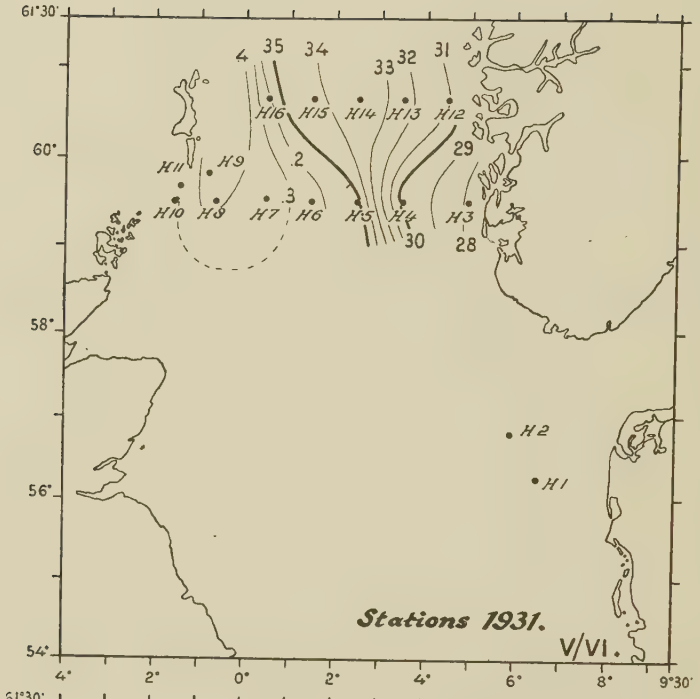

Fig. 1. Surface isohalines, June 10th—27th.

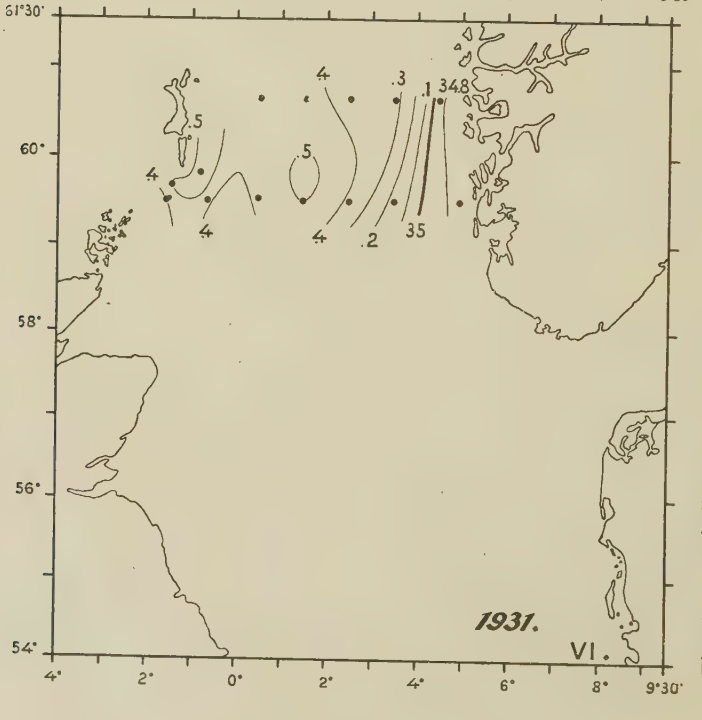

Fig. 1, a. Isohalines at a depth of 50 m., June 10th—27th.

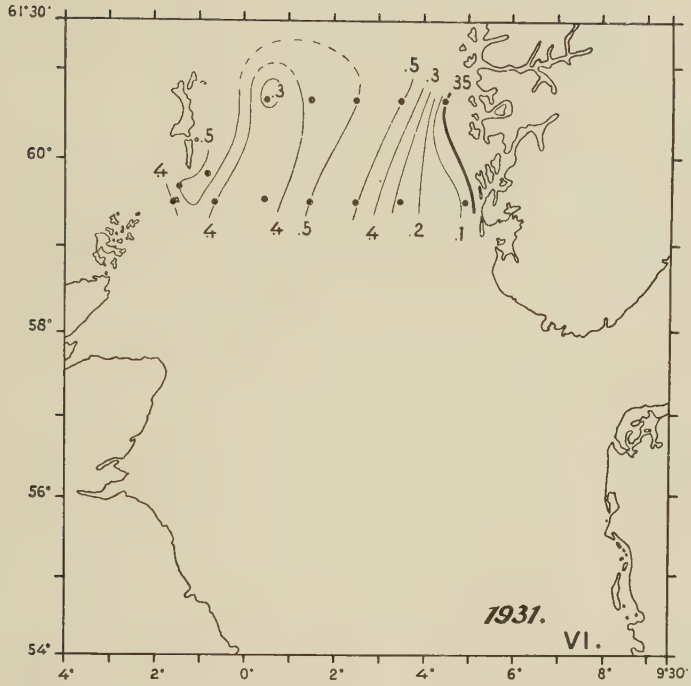

Fig. 1, b. Isohalines at a depth of 75 m., June 10th.—27th.

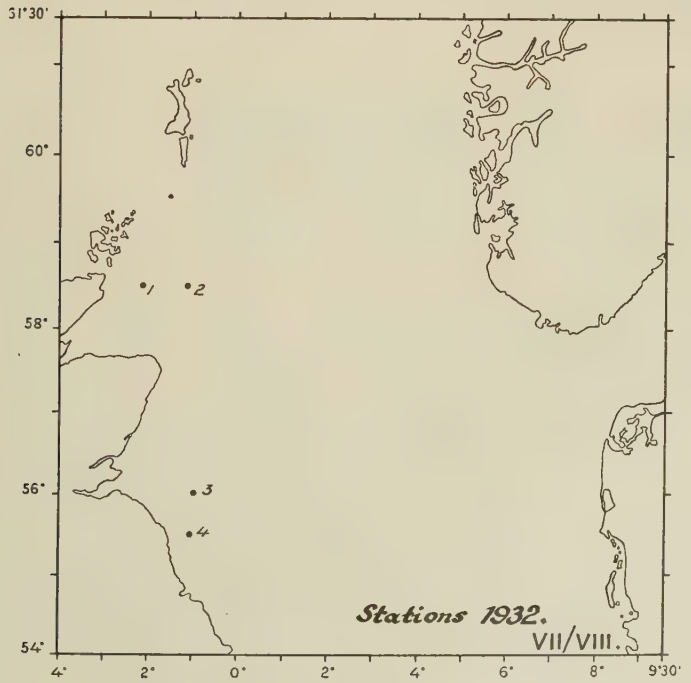

Fig. 2. Position of stations where serial observations of temperature and salinity were obtained on July 28th, 31st and August 8th.

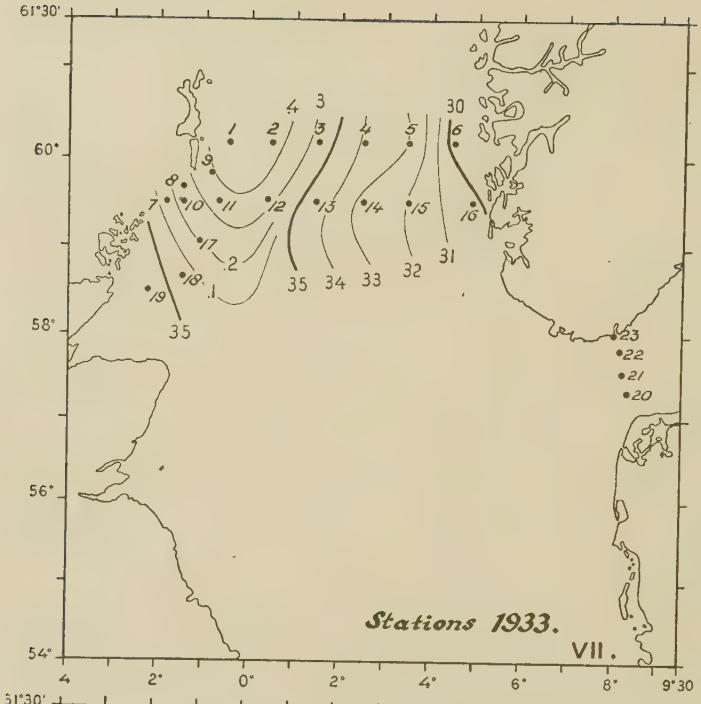

Fig. 3. Surface isohalines, July 12th—25th.

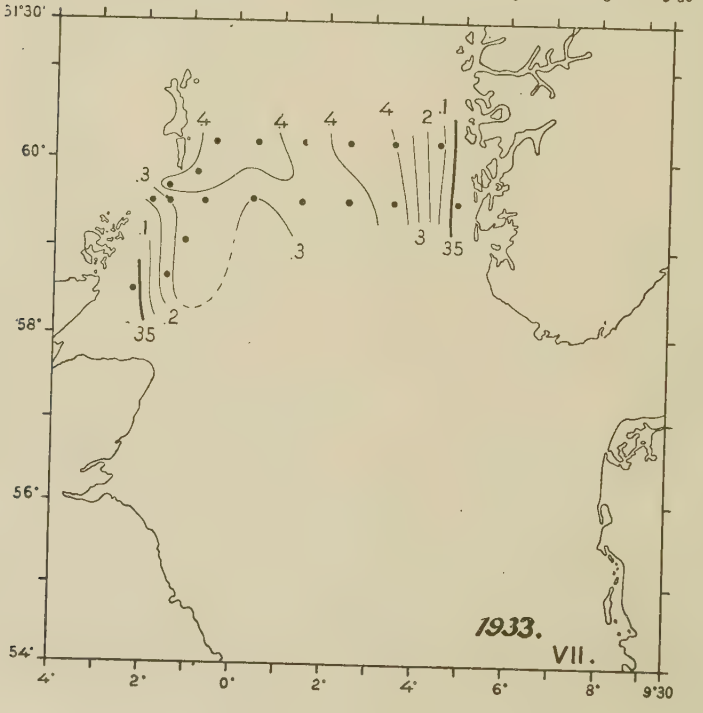

Fig. 3, a. Isohalines at a depth of 50 m., July 12th—25th.

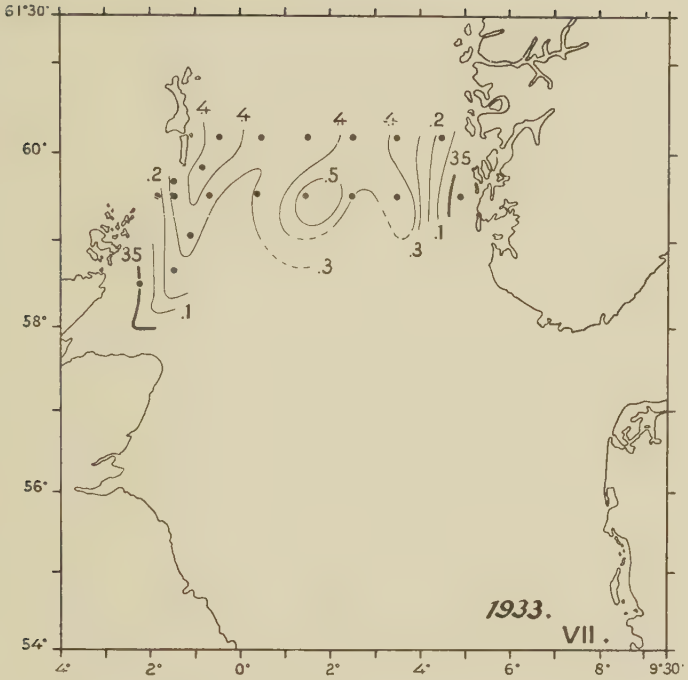

Fig. 3, b. Isohalines at a depth of 75 m., July 12th—25th.

Fig. 1 a where the salinity amounts to over 35.5 $^0/_{00}$. This area is separated from the tongue-shaped extension of the Atlantic inflow off the east coast of Shetland by the isohaline for 35.4 $^0/_{00}$. At 75 m. (Fig. 1 b) the 35.4 $^0/_{00}$ isohaline is found farther to the north, so that the inflow is divided into two tongues of 35.5 $^0/_{00}$ and over. With increasing depth the isohaline for 35.0 $^0/_{00}$ comes nearer to the Norwegian coast.

1933. In this year, the surface salinity distribution differs only slightly from that of 1931. At a depth of 50 m. (Fig. 3 a) the salinity is less than in 1931; in both years an area of lower salinity divides the oceanic inflow into two branches, which appear more distinctly in the 75 m. layer (Fig. 3 b). Here an isolated area of a salinity exceeding 35.5 $^0/_{00}$ occurs in the vicinity of station 13.

1934. Surface salinity in the western part of the area is much higher than in the previous year (Fig. 4), the isohaline for 35.4 $^0/_{00}$ extending southward as far as latitude 57°.5 N. The region of over 35.0 $^0/_{00}$ is much wider than normally. At a depth of 50 m. (Fig. 4 a) the salinity of the Atlantic flow is only a little higher than in 1933, that is, on the *west* side only. The increase of salinity *in this part* in the 75 m. layer (Fig 4 b) is considerable, compared with the foregoing year.

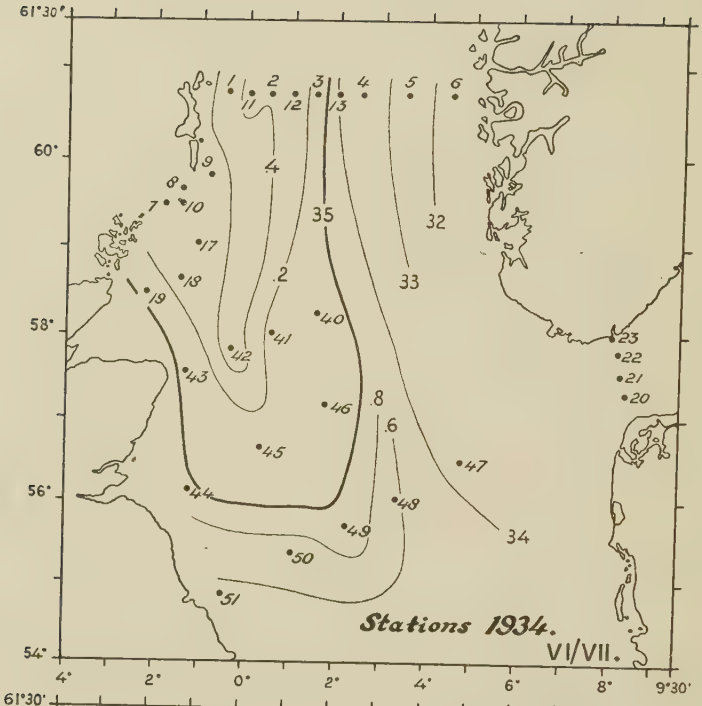

Fig. 4. Surface isohalines, June 27th—July 12th.

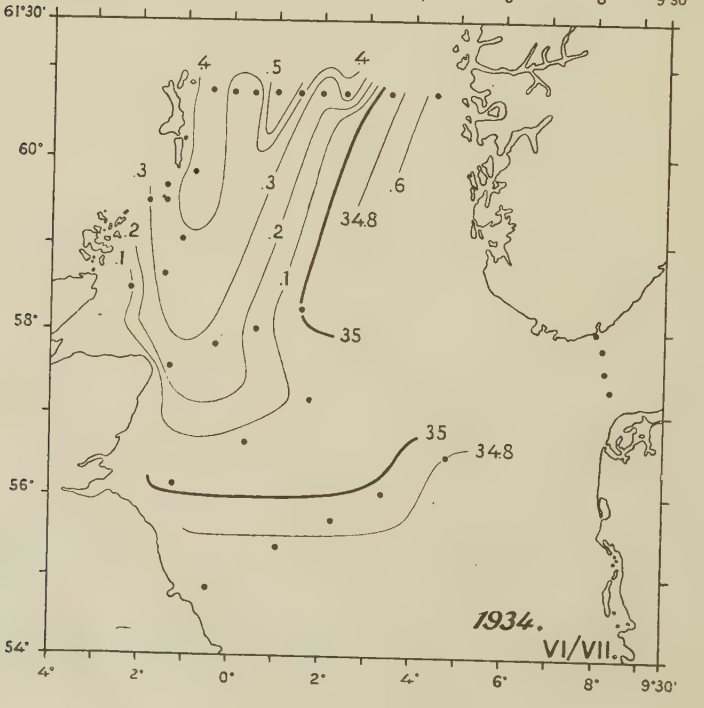

Fig. 4, a. Isohalines at a depth of 50 m., June 27th—July 12th.

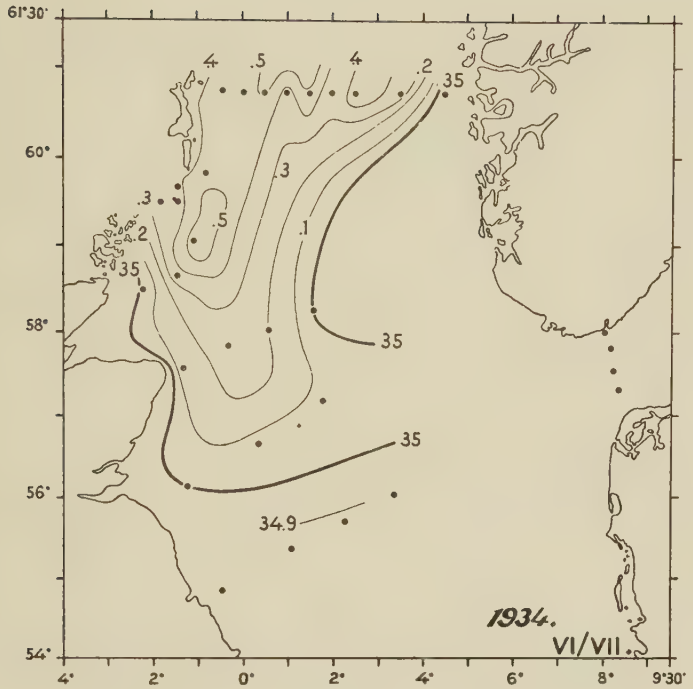

Fig. 4, b. Isohalines at a depth of 75 m., June 27th—July 12th.

Attention is drawn to the isolated region of high salinity, situated to the eastward of the Orkney Islands.

1935. In this year (Fig. 5) the surface isohalines for 35.0, 35.1 and 35.2 ‰ extend farther southward than in 1934. The width of the oceanic flow is, however, less in 1935. The isolated area of surface salinity 35.3 ‰ and over may be regarded as a remnant of the Atlantic influx after its temporary interruption. Similar isolated areas occur also at 50, 75 and 100 m. to the north-east of the Moray Firth (Figs. 5 a and 5 b), and at 50 m. between longitudes 2° and 4° E. and about latitude 56° N.

The trend of the isohalines in the deeper layers points (especially in 1934) to the occurrence of an east-going branch of the inflow of Atlantic water, which must be responsible for the rather high salinities obtained in the Skagerak.

Attention is drawn to the fact that in the deeper layers the 35.0-isohaline lies at a greater distance from the Norwegian coast in 1934 and 1935 than in 1931 and 1933. It appears that an increase of the intensity of the oceanic influx in the western part in 1934 and 1935 is accompanied by a decrease of its extension towards the east. This is confirmed by the vertical sections, representing the salinity and temperature distributions between Shetland and Norway.

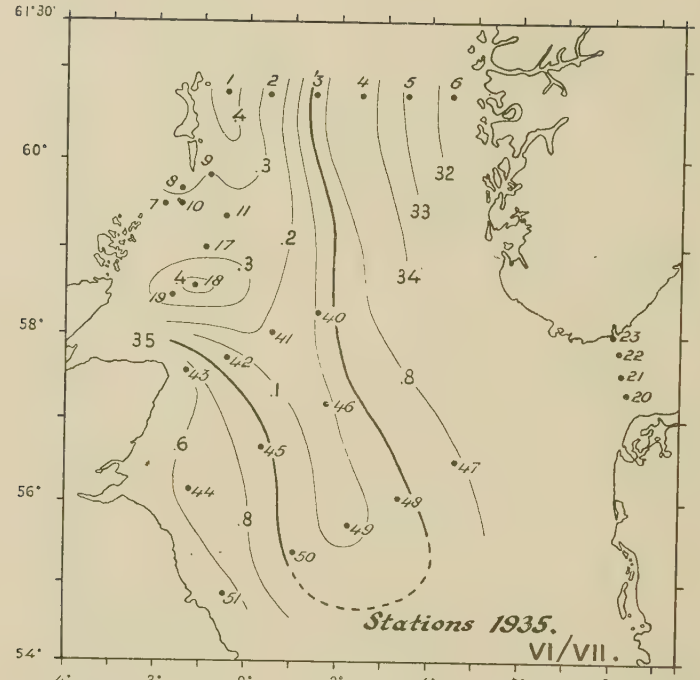

Fig. 5. Surface isohalines, June 23rd and July 3rd—23rd.

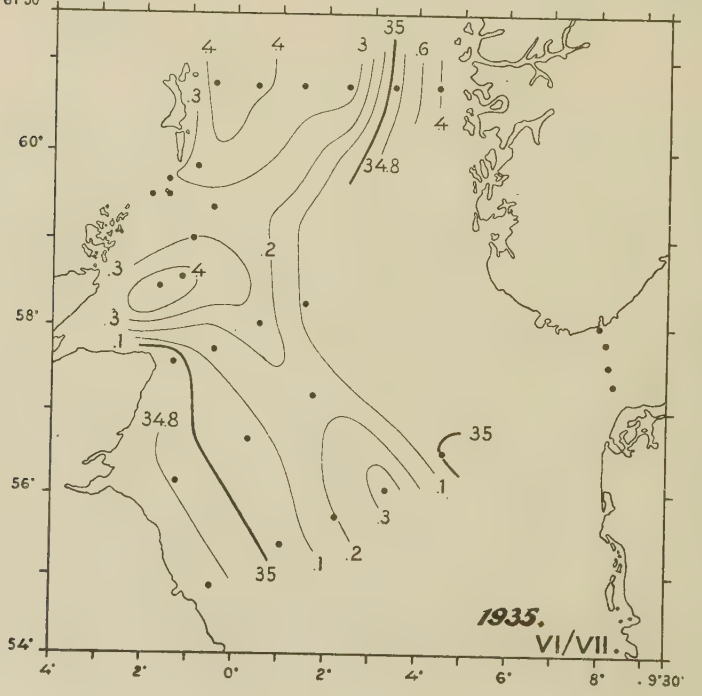

Fig. 5, a. Isohalines at a depth of 50 m., June 23rd and July 3rd.—23rd.

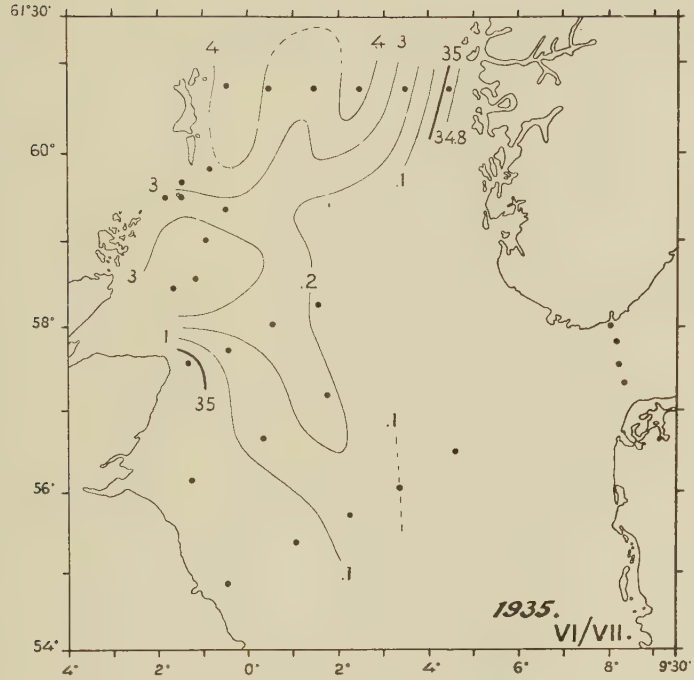

Fig. 5, b. Isohalines at a depth of 75 m., June 23rd and July 3rd—23rd.

Vertical sections. Figures 6, 7, 8 and 9 show the distribution of the temperature *in situ* and of the salinity in a vertical section between Shetland and the Norwegian coast for the years 1931, 1933, 1934 and 1935. The latitude of this section is in 1933 about 30′ more to the south than in the other years.

1931. (Fig. 6). The observations were taken on June 25th—27th. Surface salinity off the Norwegian coast is, according to the Atlas[1]), 1.2 $^0/_{00}$ below the normal value (St. H12), but in view of the large variations which occur in these coastal regions little value can be attached to this fact. The deviation from normal salinity decreases gradually towards the west and is inappreciable at station H16. The temperature of the surface water is about 10° C.

A layer of salinity 35.4 $^0/_{00}$ and over slopes from the surface in the western part to a deeper layer eastwards where salinities of over 35.5 $^0/_{00}$ were obtained at 75 m. at stations H13 and H14. Unfortunately observations from deeper layers are not available.

The temperature of the less saline bottom water in the shallower western area is less than 7° C. Between 50 and 100 m., off the

[1]) See p. 169.

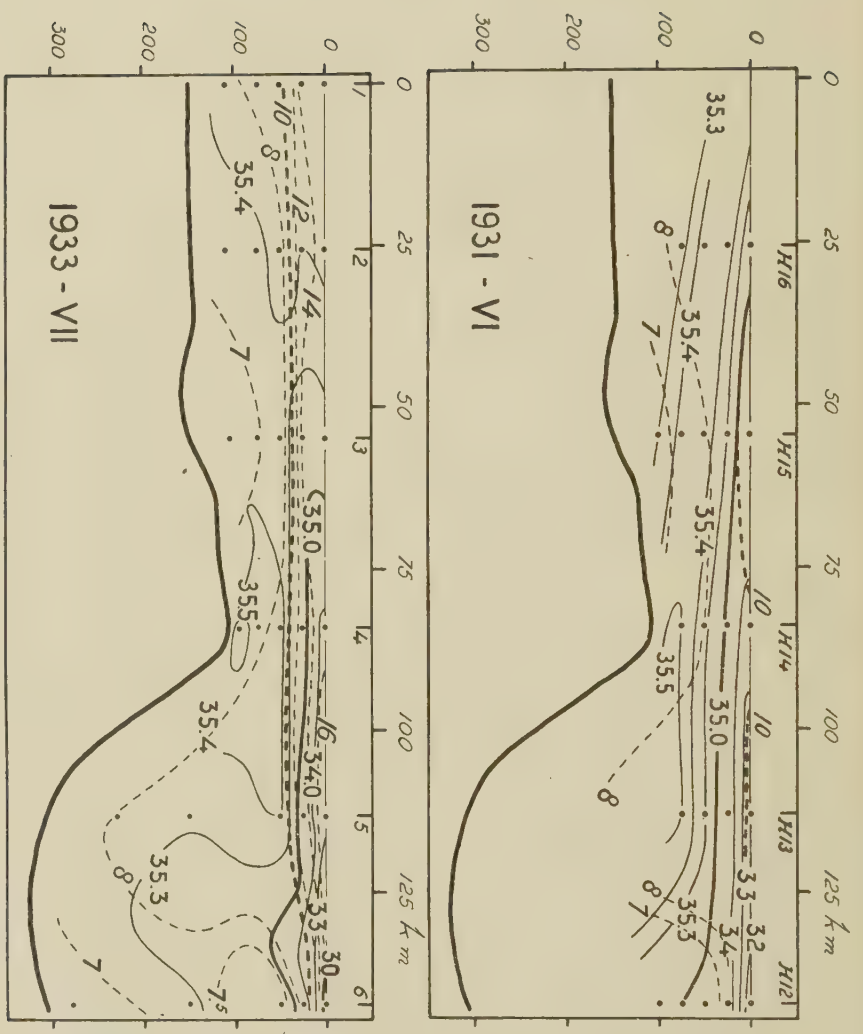

Fig. 6. Hydrographic section between Shetland and Norway, Temperature and Salinity. June 25th—27th.
Fig. 7. Hydrographic section between Shetland and Norway, Temperature and Salinity. July 18th—19th.

Norwegian coast, appears a tongue of cold water, which extends farther towards the west in the following three years. (Figs. 7, 8 and 9).

1933. (Fig. 7). The observations were obtained on July 18th—19th. Compared with conditions in 1931 the high temperature of the upper layers in 1933 is a remarkable feature which cannot be ascribed to the fact that the observations of the latter year were carried out about three weeks later than in 1931.

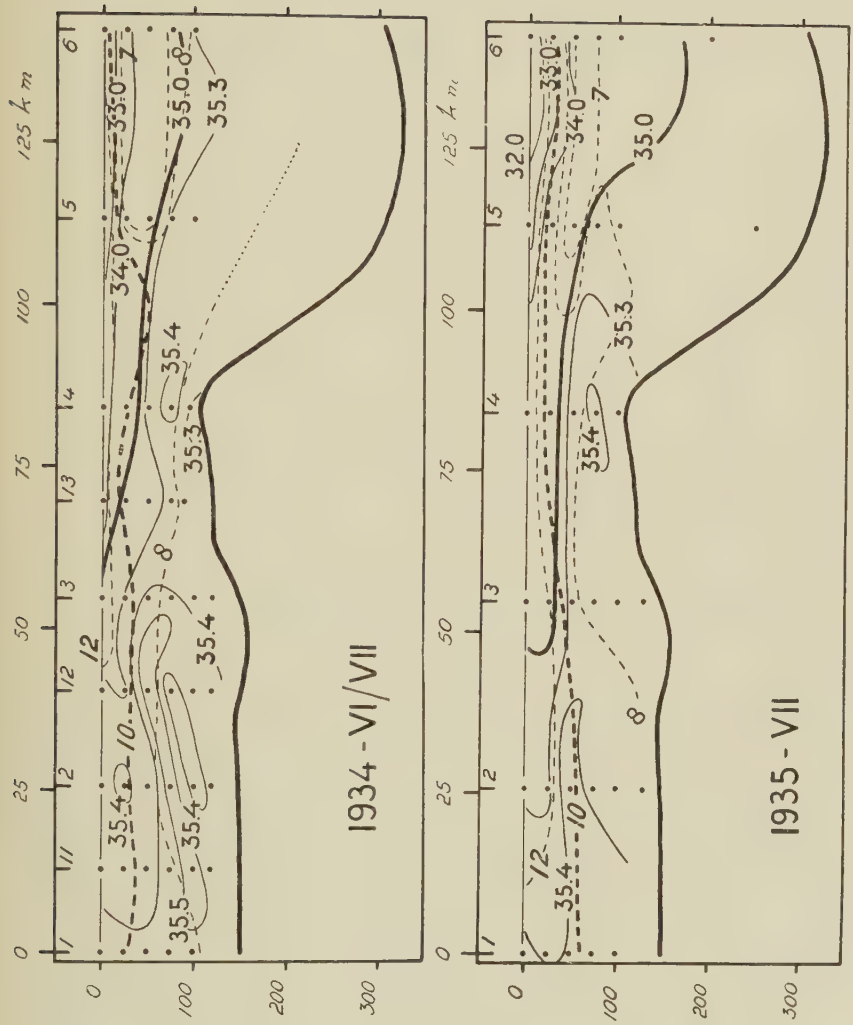

Fig. 8. Hydrographic section between Shetland and Norway, Temperature and Salinity. June 30th—July 1st.
Fig. 9. Hydrographic section between Shetland and Norway, Temperature and Salinity. July 22nd—23rd.

Off the Norwegian coast the surface salinity is about 1.7 ‰ below normal; in the west, the average deviation is of little importance. The sloping layer of 35.4 ‰ and over, observed in 1931, is interrupted in 1933 near station 3. Also, in the intermediate and deeper middle layers towards the east the salinity appears lower than in 1931. A salinity of 35.5 ‰, which occurred in 1931 at stations H13 and H14 at a depth of 75 m. was registered in 1933 only at station 4 at 95 m.

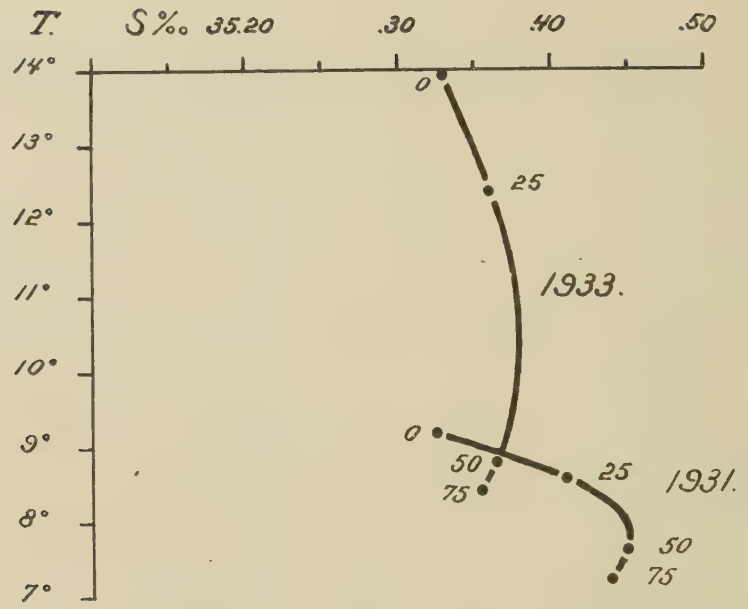

Fig. 10. TS-diagram for the mean temperature and salinity of the Atlantic inflow between 59°50′ and 59°30′ Lat. N. in 1931 and 1933.

1934. (Fig. 8). The observations were obtained on June 30th and July 1st. An increase of the salinity in the western part, where alternate layers of high and low salinity occur, coincides with a decrease in the eastern and middle part, where the area of 35.4 ‰ and over is reduced in 1934 to a small area in a depth of 75 m. at station 4. With the increase of the salinity of the bottom layers in the west temperatures below 7° C. have disappeared. The temperature of the upper layers is considerably lower than in 1933.

1935. (Fig. 9). The observations were carried out on July 22nd—23rd. The surface salinity deviates on the average only slightly from the normal value. In the deeper layers of the eastern part the salinity is less than in the previous year, the isohaline for 35.3 ‰ having withdrawn to a position between stations 4 and 5 at a depth of about 75 m. Also in the western part the area of 35.4 ‰ and over is considerably smaller than in 1934. An isolated area encircled by the isohaline for 35.4 ‰ occurs at station 4 at the same depth as in 1934.

The decrease of the salinity in the deeper layers of the western part is accompanied by an increase of temperature; also in the upper layers the temperature is here slightly higher than in 1934.

Salinity-frequencies and high salinities. When comparing the salinities obtained south-east of Shetland in 1931 at stations H7—H11 and those in 1933 at the corresponding stations 12, 11, 9, 10 and 8, it appears

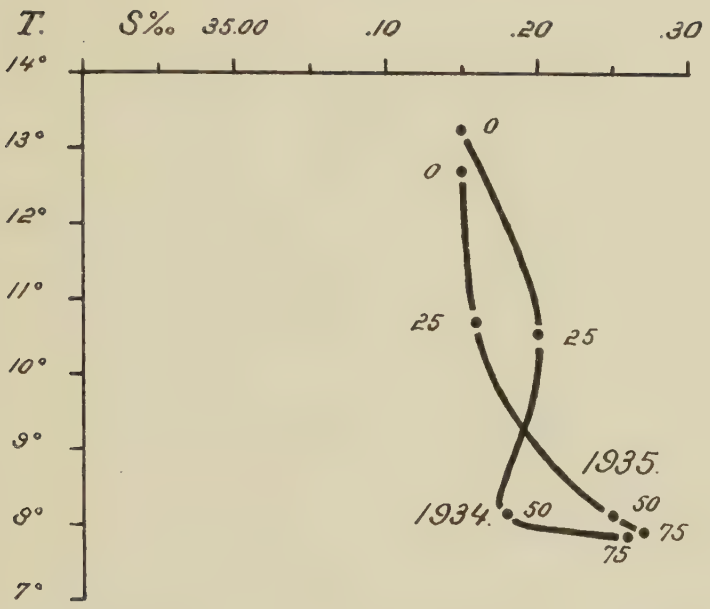

Fig. 11. TS-diagram for the mean temperature and salinity of the Atlantic inflow between 60°50′ and 55°20′ Lat. N. in 1934 and 1935.

that the mean salinity of the oceanic influx between surface and bottom differs in this region in 1931 only slightly from that in 1933 (35.41 against 35.35 ‰).

In his last report (Vol. 94) T a i t suggests the definition of *high* salinities as those in excess of 35.39 ‰ and of *extraordinarily high* records, those greater than 35.49 ‰. Making use of these definitions and considering the frequency-distribution of the salinities, the difference between 1931 and 1933 stands out more distinctly. In 1931 five extraordinarily high salinities (maximum 35.53 ‰) and nine high salinities were recorded in the above-mentioned region. In 1933 no salinities greater than 35.49 ‰ were recorded and only six in excess of 35.39 ‰ (maximum 35.48 ‰). The observations were obtained in 1931 on June 12th and 17th, in 1933 on July 13th and 18th.

In Fig. 10 we have a TS-diagram based on the mean values of temperature and salinity which have been calculated for the above-mentioned stations situated in the Atlantic inflow. This diagram shows most clearly the higher mean salinity in nearly all levels in 1931 and the higher mean temperature in 1933. The values 9° C. and 35.37 ‰ occurring in 1931 at a depth of 10 m. were registered in 1933 at about 50 m.

The large number of observations obtained in 1934 and 1935 allows comparison of the salinity of the Atlantic water, entering the North Sea, in a more extensive region, embracing stations 1—4, 9, 17—19, 40—46 and 48—50. Observations were obtained in 1934 from 9th to

12th July at Stats. 40, 41, 45, 46 and 48—50; at the other stations, from June 27th to July 1st; in 1935 on July 3rd to 8th at Stats. 18, 19, 40, 42, 43, 45, 48; from July 18th to 23rd at Stats. 1—4, 9, 17, 41 and 46; on June 23rd at Stats. 49 and 50. The extraordinarily high salinities recorded on June 30th, 1934, at station 11 at 100 m. (35.62 $^0/_{00}$) and at station 12 at 50 m. (35.59 $^0/_{00}$) have not been considered here as no observations were available for 1935 at these stations. They appear, however, as a layer of high salinity in Fig. 8.

Fig. 11 is a TS-diagram based on the mean temperatures and salinities, from the above-mentioned stations, except station 4, which only partly belongs to the Atlantic inflow, being situated in the region of transition from oceanic to continental water. The differences in temperature appear to be small. Mean salinity at a depth of 50 m. in 1934 is lower than in 1935; at 25 m. the opposite is the case.

The frequency-distribution of salinities in this region of the Atlantic influx is a follows:

Frequency-Distribution of Salinities in the region of Atlantic influx in the North Sea.

Year	No. of salinities	>35.49	30.40 / 35.49	35.30 / 35.39	35.20 / 35.29	35.10 / 35.19	35.00 / 35.09	<35.00
1934	78	3	14	18	8	13	10	12
1935	78	—	9	25	8	16	10	10

From this table it appears that the frequency of high and extraordinarily high salinities decreased in 1935, as was anticipated by Tait[1]).

The same author has dealt thoroughly with the question of whether any appreciable Atlantic influx occurs between Scotland and Shetland. In his opinion "it appears that the essential current connection (of Atlantic water) between the Faroe-Shetland Channel and the Northern North Sea lies by way of the north of Shetland and the Shetland-Norway opening". The above-mentioned hydrographical facts support his opinion; neither at the surface, nor in the deeper layers is there evidence of an influx of Atlantic water of high salinity between Orkney and Shetland.

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[1]) Rapp. et Proc.-Verb., Vol. 94, III, p. 64.

The Effect of Salinity and Temperature upon the Dissociation of Cresol Red and Phenol Red in Sea Water.

By

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THE desirability of greater precision in measurements of the pH of sea water has been felt by many observers. An approach to this end was presented by Mitchell and Taylor (1) in the form of pK′ values for o-cresol red in various dilutions of sea water at 20° C. and at 30° C. The values were determined for use in colorimetric measurements of sea water pH by the bicolorimeter method. The precision of this method encounters a limiting factor in the inaccuracy of information regarding changes in the dissociation of the indicator with changes in the salinity and temperature of the water sample. If information regarding the behavior of the indicator were sufficiently precise, there should be no difficulty in determining the pH of sea water with an accuracy which would give unquestioned significance to the second place of decimals.

This report confirms and extends the data previously presented for o-cresol red, presents values obtained at 25° C. and also gives values for phenol red in sea water of various salinities at 20° C. and at 25° C.

The use of a constant-temperature room in which the thermostats for the electrodes and for the colorimeter were placed gave more satisfactory temperature control than in the case of measurements previously reported. The procedure was similar in principle to that used by Mitchell and Taylor. Each sample of sea water under observation was diluted with distilled water to varying degrees, giving a series of samples of graded salinity. The original sample and each of its dilutions were then measured with a glass electrode to obtain the pH and were read in the bicolorimeter (Hastings design, Bausch and Lomb model) either immediately before or immediately after the electrode measurement. The glass electrode and its arrangement were as described by MacInnes and Belcher (2). The electrode has a comparatively large tubular surface and the potential

between it and a saturated calomel electrode is read from a type *K* potentiometer using a Compton electrometer as a null point instrument. The glass electrode potentials were parallel, for standard buffer solutions, to those given by the same solutions with the hydrogen electrode at the same temperature. The electrometer was adjusted to a sensitivity giving approximately 6 mm. of movement of the reflected light along the scale for 0.001 volt. Readings were made to 0.00005 volt. The glass electrode was standardized with buffer solutions of known pH before and after each set of measurements and showed a satisfactory degree of stability of its asymmetry potential. Variations were less than 0.001 volt in the course of a week provided the temperature and the position of the electrode were maintained in a steady state.

In order to reduce to a minimum any changes in the CO_2 tension of the water sample during the time that measurements were being taken, 500 ml. of each sample were mixed with the required amount of indicator solution in a narrow separatory funnel and only the portion in the lower part of it was used for rinsing and filling the glass electrode and the bicolorimeter cups. This precaution was found to be necessary for reproducible results as the respiration of the observer caused a rising CO_2 content of the air of the constant temperature room. Duplication of results, however, was such as to indicate that the CO_2 content of the water was controlled satisfactorily during the taking of a set of measurements. If small samples are to be used some device for transfer of the sample to the colorimeter cup without exposure to air and for keeping the cup closed during measurements would be desirable. A cover for the cup was tried in the form of rubber sheeting perforated to admit the plunger but was found inconvenient to use. In this form of bicolorimeter, however, the cup containing the portion of sample to be observed is only slightly larger in diameter than its plunger so that if a sufficient streaming of the sample through the cup is permitted and the latter is quickly put in place and plunger inserted, satisfactorily reproducible results are obtained. In a series of readings either with the same or with different fillings of the cup extending over a period of 10 minutes the variability of the readings is no greater with diluted sea water of low buffering capacity than it is with a well-buffered standard solution.

The salinity of each sample and its various dilutions was measured by the usual silver nitrate titration.

The pK′ value of the indicator was obtained by subtracting the log. of the ratio of the depth of the standard alkaline solution to the depth of the standard acid solution at the matching point from the pH of the water as obtained by the use of the glass electrode.

$$pK' = pH - \log \frac{y - x}{x}$$

where y is the total depth of the two standard solutions and x is the depth of the acid one.

In some of the measurements, however, observations were taken

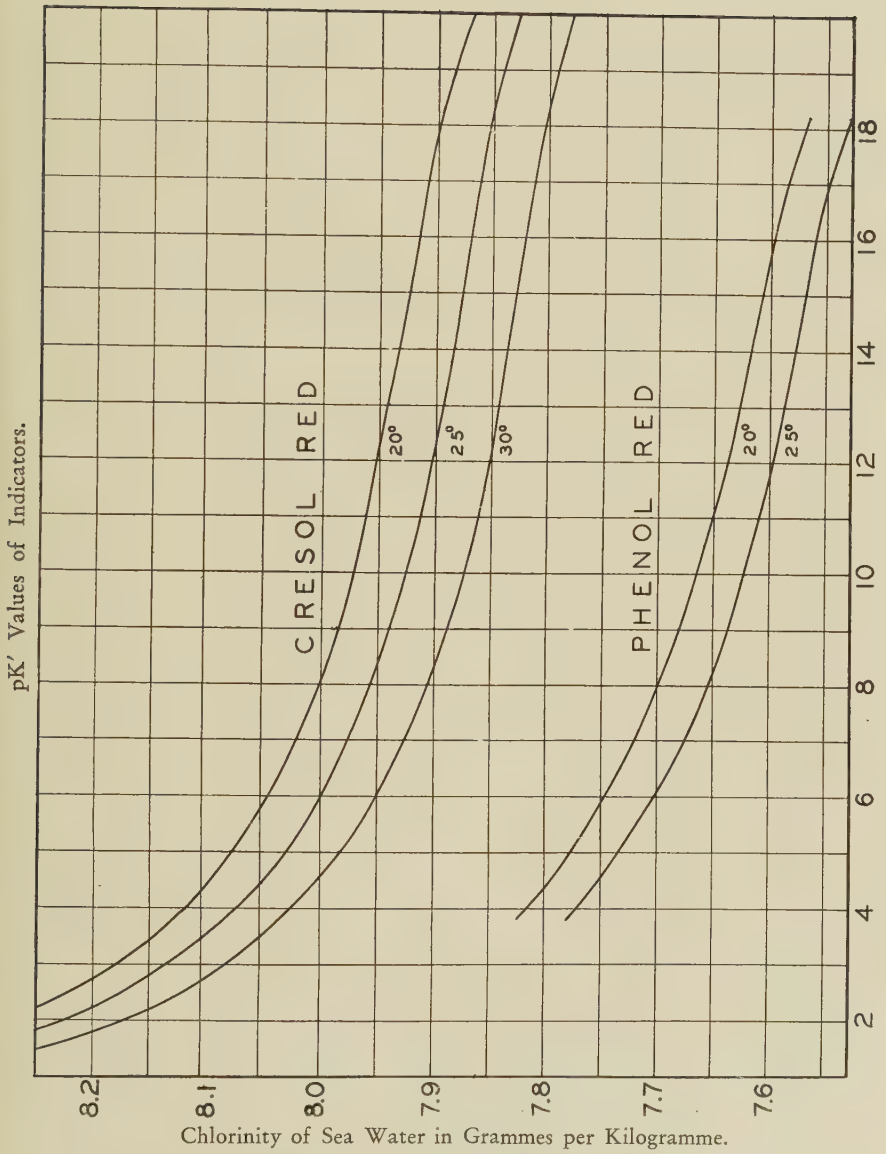

Fig. 1. — The pK′ Values of Cresol Red and Phenol Red as influenced by the salinity and temperature of sea water.

by the colorimetric method of B u c h (3) comparing sea water samples containing o-cresol red with Palitzsch standard borate buffer solutions, while the same sea water sample was measured for pH in the glass electrode. In this case the difference between the two results was taken as the "salt error". Values thus obtained, when subtracted from the pK′ value of the indicator as measured in these standard borate solutions

gave results in good agreement with those obtained by the use of the bicolorimeter.

Typical results are presented in Tables 1, 2, and 3. Duplicate measurements on the same sample are shown in order to indicate the degree of the probable error of the observations which is approximately ± 0.007. The results are summarized in graphic form in Fig. 1, in which the curve for pK′ of o-cresol red at 30° C. is taken from Mitchell and Taylor (1) for purposes of comparison; the curve for o-cresol red at 20° C. is constructed from a composite of results previously obtained together with the newer data obtained under conditions of better temperature control; and the other three curves represent new measurements only.

Table 1. pK' Values of o-Cresol Red in Sea Water.

Chlorinity of sample		Salinity of sample	Glass electrode result	Bicolorimeter result	pK′
grammes per litre	grammes per kilo	grammes per kilo	pH	$\log \frac{y-x}{x}$	at 20° C
19.50	19.04	34.40	7.868	9.995 — 10	7.873
			7.866	9.991 — 10	7.875
17.42	17.04	30.79	7.803	9.898 — 10	7.905
			7.735	9.840 — 10	7.895
13.48	13.25	23.95	7.699	9.772 — 10	7.937
			7.654	9.712 — 10	7.942
10.03	9.90	17.89	7.652	9.672 — 10	7.980
			7.607	9.636 — 10	7.971
9.91	9.79	17.70	7.983	9.998 — 10	7.985
			7.985	9.993 — 10	7.992
8.00	7.92	14.33	7.912	9.912 — 10	8.000
			7.914	9.912 — 10	8.002
5.89	5.85	10.59	7.809	9.766 — 10	8.043
			7.793	9.773 — 10	8.020
4.00	3.98	7.21	7.504	9.350 — 10	8.153
			7.450	9.325 — 10	8.125
					at 25° C
18.20	17.79	32.14	7.780	9.947 — 10	7.833
			7.779	9.915 — 10	7.864
17.67	17.27	31.20	7.908	0.058	7.850
			7.908	0.052	7.856
16.18	15.85	28.64	7.939	0.090	7.849
			7.941	0.078	7.863
13.72	13.50	24.41	7.940	0.041	7.899
			7.938	0.037	7.901
12.14	11.96	21.62	7.905	9.994 — 10	7.911
			7.905	9.994 — 10	7.911
8.18	8.10	14.65	7.825	9.852 — 10	7.973
			7.823	9.860 — 10	7.963

Table 2. pK' Values of Phenol Red in Sea Water.

Chlorinity of sample		Salinity of sample	Glass electrode result	Bicolorimeter result	pK'
grammes per litre	grammes per kilo	grammes per kilo	pH	$\log \frac{y-x}{x}$	at 20° C
17.84	17.43	31.49	7.973	0.404	7.569
			7.985	0.404	7.581
16.16	15.86	28.66	8.005	0.396	7.609
			8.004	0.396	7.608
14.07	13.83	24.99	7.976	0.355	7.621
			7.970	0.348	7.622
12.07	11.89	21.49	8.000	0.355	7.645
			7.976	0.348	7.628
10.37	10.25	18.53	8.051	0.396	7.655
			8.000	0.328	7.672
10.06	9.94	17.79	7.941	0.268	7.673
			7.935	0.266	7.669
8.14	8.06	14.58	8.002	0.288	7.714
			7.987	0.266	7.707
5.94	5.90	10.68	7.943	0.158	7.785
			7.890	0.146	7.744
3.93	3.91	7.09	7.663	9.854 — 10	7.809
			7.673	9.847 — 10	7.826
					at 25° C
18.20	17.79	32.14	7.921	0.381	7.540
			7.912	0.381	7.538
16.25	15.84	28.62	7.879	0.320	7.559
			7.944	0.382	7.562
14.03	13.78	24.90	7.950	0.371	7.579
			7.944	0.368	7.577
12.17	11.99	21.67	7.942	0.343	7.599
			7.939	0.341	7.598
10.34	10.21	18.45	7.725	0.114	7.611
			7.736	0.111	7.625
8.35	8.27	14.96	7.630	9.976 — 10	7.654
			7.624	9.976 — 10	7.648
6.25	6.21	11.24	7.531	9.830 — 10	7.701
			7.517	9.823 — 10	7.694

Table 3. "Salt Correction" for o-Cresol Red in Sea Water at 20° C. to be used in connexion with the buffer solutions of Palitzsch.

Sample No.	Chlorinity of sample	Salinity of sample	Glass electrode result	Colorimetric result	"Salt Correction"
	grammes per kilo	grammes per kilo	pH	pH	
1	17.54	31.69	7.941	8.19	0.25
			7.941	8.18	0.24
2	11.80	21.33	7.906	8.115	0.21
			7.826	8.07	0.24
3	8.90	16.09	7.945	8.13	0.185
			7.945	8.13	0.185
4	5.93	10.73	7.946	8.075	0.13
			7.944	8.075	0.13
5	3.59	6.51	7.917	7.97	0.05
			7.910	7.96	0.05
6	1.80	3.25	8.073	(8.07)	(0.00)
			8.015	(8.02)	(0.00)

To samples 2—5 some sodium carbonate was added so that these had the same titration alkalinity as no. 1. Sample no. 6 was made from no. 5 by dilution. The result of no. 6 is to be considered as somewhat less accurate than the others. All values were used for calculating, by the method of least squares, the following equation showing the relation between the salt error and the salinity between 3 and 35 ‰

$$\text{salt correction} = 0.373 - 0.257\sqrt[3]{S + 0.006 \cdot S.}$$

In calculating this equation the increase in salinity — less than 0.1 ‰ — caused by the addition of sodium carbonate, was considered. It is obvious that these corrections can be used only when the buffer solutions of Palitzsch are used as standards.

It is obvious that pK′ values as presented in these curves can be used in practical measurements only if the indicator to be employed is of the same purity and composition as that used for these standardizations. The variability of the behavior of commercial indicators is too well known to require comment. The cresol red and phenol red used for these measurements were from LaMotte Chemical Products Co., purchased as 1 % solution and diluted with distilled water to 0.02 % and 0.04 % respectively. In each case 1 part of the diluted indicator solution was added to 20 parts of the sea water or standard solution. The behavior of the indicators is characterized by the data presented in Table 4.

Table 4. Characteristics of the Indicators Used.

	pK′ in Sørensen M/15 standard phosphate buffers, pH 7.4 – 8.0		pK′ in Clark and Lubs standard borate KCl buffers, pH 7.5 – 8.0	
	at 20° C	at 25° C	at 20° C	at 25° C
o-Cresol red	8.06	8.01	8.17	8.11
Phenol red	7.75	7.72	7.84	7.81

The effect of temperature upon the dissociation of the indicator is seen to be such that a satisfactory estimation of the pK′ of o-cresol red in a solution of given ionic content at temperatures in the neighborhood of 20° C. can be computed by the formula

$$pK'_t = pK'_{20} - 0.01\ (t - 20)$$

where pK′ is the value at the prevailing temperature, t, and pK'_{20} is the value in the same solution at 20° C. For phenol red, the formula is

$$pK'_t = pK'_{20} - 0.007\ (t - 20)$$

which is in agreement with values for the effect of temperature upon phenol red as reported by Kolthoff (4). It is thus apparent that the temperature effect upon o-cresol red is greater than it is upon phenol red.

If the values represented by the curves in Fig. 1 are to be used in connexion with measurements of the pH of sea water in a bicolorimeter, it is only necessary to read off the pK′ value of the indicator above the point corresponding to the chlorinity of the sample, interpolating for the temperature effect. But if these values are to be employed in connexion with colorimetric comparison with standard tubes, it becomes necessary to know the pK′ of the indicator in the standard solutions used at the prevailing temperature. From this value the pK′ at the chlorinity and temperature of the water sample is to be subtracted to give the "salt correction".

Summary.

The effect of the salinity of sea water and the effect of temperature upon the dissociation of o-cresol red and phenol red are shown in the form of pK′ values to be used in the colorimetric measurement of the pH of sea water.

References.

(1) Mitchell, P. H., and I. R. Taylor, J. du Cons. Inter. pour l'Explor. de la Mer. X, 169 (1935).
(2) MacInnes, D. A., and D. Belcher, J. Ind. and Eng. Chem. Anal. Ed., 5, 199 (1933).
(3) Buch, Kurt. Finska Kemistsamfundets meddelanden Nr. 3 1934 (Finland, Helsingfors).
(4) Kolthoff, I., J. Phys. Chem., 34, 1466 (1930).

Sampling Variations in the Use of Plankton Nets.

By

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A considerable literature exists relative to the accuracy of quantitative plankton studies based on the use of various types of nets. So far as we have been able to learn, however, there has been very little attempt at a study of the sampling variations actually found. It is our purpose in the present paper to examine the available published data with a view to determining the nature and extent of the sampling variations encountered, so far as this is practicable.

Hensen (1887) discusses the variation to be expected in vertical hauls. He made several series of parallel hauls, with resulting coefficients of variation in the total volume of the catch of the order of 10 to 15 %. Lohmann (1903) made a further examination of this data, and concluded that one may expect variations of 20 to 30 % in the number of organisms of a particular species; but that for certain types the variation may be much greater.

Herdman (1921) carried out a number of similar experiments at Port Erin, taking care to select days and hours when tide and weather conditions were as nearly ideal as possible for making comparable repeated vertical hauls. In seven series of four to six hauls, he found the percentage deviation from the mean number of each class of organisms ranged from 14 % to 121 %. Unfortunately, he does not give details of the individual hauls to permit us to make further calculations with his data, nor does he offer any sampling theory by which the probable error of other plankton hauls can be calculated.

Gardiner and Graham (1925) made a series of 10 oblique hauls with a Petersen's young fish trawl to determine the working error of this apparatus. They calculated the standard deviation, which, expressed in percentage of the mean, varied between 27 % and 54 %. Like Herdman, however, they give no basis for determining the probable error of other hauls.

Gardiner's (1931) study of the international net is perhaps the most elaborate and carefully planned of which we are aware. He concludes that about 75 % of hauls will not deviate by more than 33 % from the mean of a long series; but that isolated deviations may reach

90 %. He does not give actual catches, but organisms per metre depth, based on "two, or more, separate samples" "in the majority of cases". While we have been unable to use his data in our own computations, we feel that his results are in essential agreement with those which we present below.

In the study of sampling variations, we are interested in the variations occurring in the numbers of organisms caught in hauls made at the same time and place, with the same technique. Ideally, the problem may be stated in terms of an urn schema. We have a container with a very large number of black and white balls, from which we draw samples. We should like to know how the numbers of black balls in successive samples may be expected to vary. The ideal method would evidently be to make a very large number of trials from the same container; but this is impossible, if only because the container (in our case, the particular spot in the ocean) and its contents cannot be expected to remain unaltered over the time necessary to draw our samples. We are therefore forced to draw a limited number of samples from each of a number of different containers. This is not necessarily a disadvantage; in fact, it has some obvious advantages, since in this way we may perhaps eliminate the special peculiarities of one particular locality.

The data we need are, in principle, the numbers of organisms actually caught in each haul; or, where the total catch is not counted, we require the number counted and the fraction that the number counted was of the whole catch. Unfortunately, in many cases it is impossible to determine these figures from actual published data; such cases are of no use for the present study.

Two sets of data have been found which meet our basic requirements. The first of these is a series of counts of fish eggs, made over a period of years (1902—1909) at Heligoland. These we shall refer to as the Ehrenbaum-Strodtmann series. (The individual references are given in the bibliography.) The catches were made with the Hensen egg net; the counts are total counts. The original counts are subdivided by species, but we have used only total eggs, since in most cases a single species predominates heavily.

The second series is taken from an investigation by Künne (1929, 1933) on the relative catching power of different types of nets. The counts here are total counts. The animals counted were of such a size as to preclude the possibility of loss by escape through the mesh of the net. The Hensen net was used throughout as a standard with which other nets were compared. We have accordingly worked up our results largely on the Hensen net; but, as will appear, there seems to be no reason to suppose that other nets differ very markedly from the Hensen net.

The problem of plankton sampling resembles in some respects the problem of estimation of bacterial numbers, especially by the method of plate counting. It therefore seemed possible that the sampling fluctuations in the two cases might be subject to essentially the same

laws. In bacterial plate counts it has been shown by Fisher, Thornton, and MacKenzie (1922) that the Poisson distribution gives a good description of the facts in cases where the technique is adequately controlled. We accordingly proceeded to investigate whether the same law might hold here. (For the theory involved, see the Appendix).

For this purpose we computed, for each pair of observations, the quantity

$$\chi^2 = S\frac{(n-\bar{n})^2}{\bar{n}^2} = \frac{(n_1-n_2)^2}{n_1+n_2} \quad (1)$$

If the basic distribution were truly Poisson, this χ^2 should, in a number of random samples, have a mean value = 1, and should be distributed in a known manner. We may conveniently test this by making up a frequency distribution of the values of χ^2 found, as shown in Table I.

Table I.

Distribution of values of χ^2.

χ^2	Proportion of cases expected	E. – S.	Künne-Hensen net	Künne-other nets	All nets
0—.016	0.1	34	13	13	60
—.064	0.1	33	13	16	62
—.148	0.1	16	18	19	53
—.275	0.1	19	17	23	59
—.455	0.1	29	24	25	78
—.708	0.1	22	16	13	51
—1.074	0.1	28	25	22	75
—1.642	0.1	32	32	21	85
—2.706	0.1	39	25	29	93
—6.635	0.09	40	47	42	129
over 6.635	0.01	38	44	31	113
	Total cases	330	274	254	858

Notes

(1) Only hauls with $n_1 + n_2 > 9$ are included in the table.

(2) The χ^2 classes have been chosen to give equal expectancies in each class, except the last two.

It is at once apparent that the distribution is very far from the theoretical. There is a great excess of large values of χ^2; which means that there is an excess of samples showing relatively large differences between hauls.

We may inquire whether there is any indication in Table I that different workers, or different nets, may vary in the distribution of their deviations. The three distributions, E.-S., Künne-Hensen, and Künne-other nets, have therefore been treated as a contingency table. The value of χ^2 turns out to be 28.36, with 20 degrees of freedom. The corresponding value of P is very nearly 0.10. There is thus no adequate ground for asserting the existence of differences in the distribution of deviations.

To obtain further light on the nature of the discrepancy, we tabulated the totals of the χ^2 values classified by sample size. Section A of Table II shows the result for all samples obtained with the Hensen net, and Section B the result for all nets. It is clear from this table that the larger hauls furnish more than their share of the high values of χ^2, as indicated by the increase in mean χ^2 with increasing size of sample.

It is thus apparent that the sampling distribution departs from the Poisson in that the differences between hauls are larger than would be expected, and further, that with increasing haul size these discrepancies increase.

This suggests that in addition to the random distribution of organisms, other factors are operative in producing sampling deviations[1]). We may then suppose that the variation actually observed is the result of (a) variations in the distribution of organisms and (b) variations in the mode of sampling. Under (b) are to be included such factors as variations in speed of hauling, deviation of the haul from the vertical, completeness of washing of the net, etc. In general, most

Table II.

Values of total and mean χ^2 for hauls of different sizes.

A. Hensen Nets				B. All Nets			
Total catch	Number of pairs	s (χ^2)	Mean χ^2	Total catch	Number of pairs	s (χ^2)	Mean χ^2
9—18	97	166.87	1.720	9—18	155	247.21	1.595
32	90	139.47	1.550	32	125	174.89	1.398
50	79	144.60	1.830	50	110	201.72	1.834
72	65	160.11	2.463	72	83	199.58	2.405
98	67	165.84	2.475	98	84	191.52	2.280
128	36	59.45	1.651	128	47	112.48	2.393
162	41	109.31	2.666	162	49	162.80	3.322
200	22	108.15	4.916	200	34	178.52	5.251
242	28	333.34	11.905	242	37	347.27	9.386
288	9	87.67	9.731	288	16	140.38	8.148
338	17	160.77	9.457	338	23	202.17	8.790
392	11	153.87	13.988	392	14	160.65	11.475
450	13	206.73	15.902	450	14	208.23	14.874
578	15	248.53	16.769	578	23	299.47	13.020
over 578	14	282.38	20.170	722	12	189.43	15.786
				over 722	32	899.07	28.096

[1]) The suggestion for this treatment was derived from Berkson, Magath, and Hurn's (1935) study of chance fluctuations of erythrocyte counts.

of the variations under (b) will be independent of the variations under (a). We can then write

$$\sigma_n^2 = \sigma_P^2 + \sigma_S^2 \qquad (2)$$

where σ_n is the standard deviation of the total catch, σ_P the standard deviation which would be observed were there no variation under (b), and σ_S that which would be observed with no variation under (a).

We may further observe that most of the factors to be placed under (b) may be thought of as essentially acting through their effect on the volume of water filtering through the net. If we assume that variation under (b) arises essentially through variations in volume of water sampled, then, as shown in the appendix, we may write

$$\sigma_n^2 = m + m^2 \frac{\sigma_v^2}{\bar{v}^2}$$

where σ_v = standard deviation of volume filtered
$\bar{v}$ = mean volume filtered
m = mean number of organisms which would be caught in a great number of hauls.

This may also be written

$$\frac{\sigma_n^2}{m} = 1 + m \frac{\sigma_v^2}{\bar{v}^2} \; ;$$

or, since our best estimate of $\frac{\sigma_n^2}{m}$ is given by χ^2, and of m is $\frac{n_1 + n_2}{2} = \bar{n}$, we have finally

$$\chi^2 = 1 + \bar{n} \frac{\sigma_v^2}{\bar{v}^2} = 1 + K^2 \bar{n} \; . \qquad (3)$$

In Fig. 1 the mean values of χ^2 from Table II have been plotted against $\bar{n}$. It is at once clear that the points are far too irregularly distributed to determine the value of K^2 with any precision. We have actually drawn a line which gives K^2 a value of 0.05; but anything between $K^2 = 0.04$ and 0.06 would give nearly as satisfactory a fit.

If we accept $K^2 = 0.05$ as a reasonable approximation, the standard deviation of a single observation is

$$\sigma = \sqrt{n + .05\, n^2} \qquad (4)$$

and the coefficient of variation, which we take as a measure of the relative accuracy of estimate, is

$$\frac{\sigma}{n} = 100 \sqrt{\frac{1}{n} + .05}. \qquad (5)$$

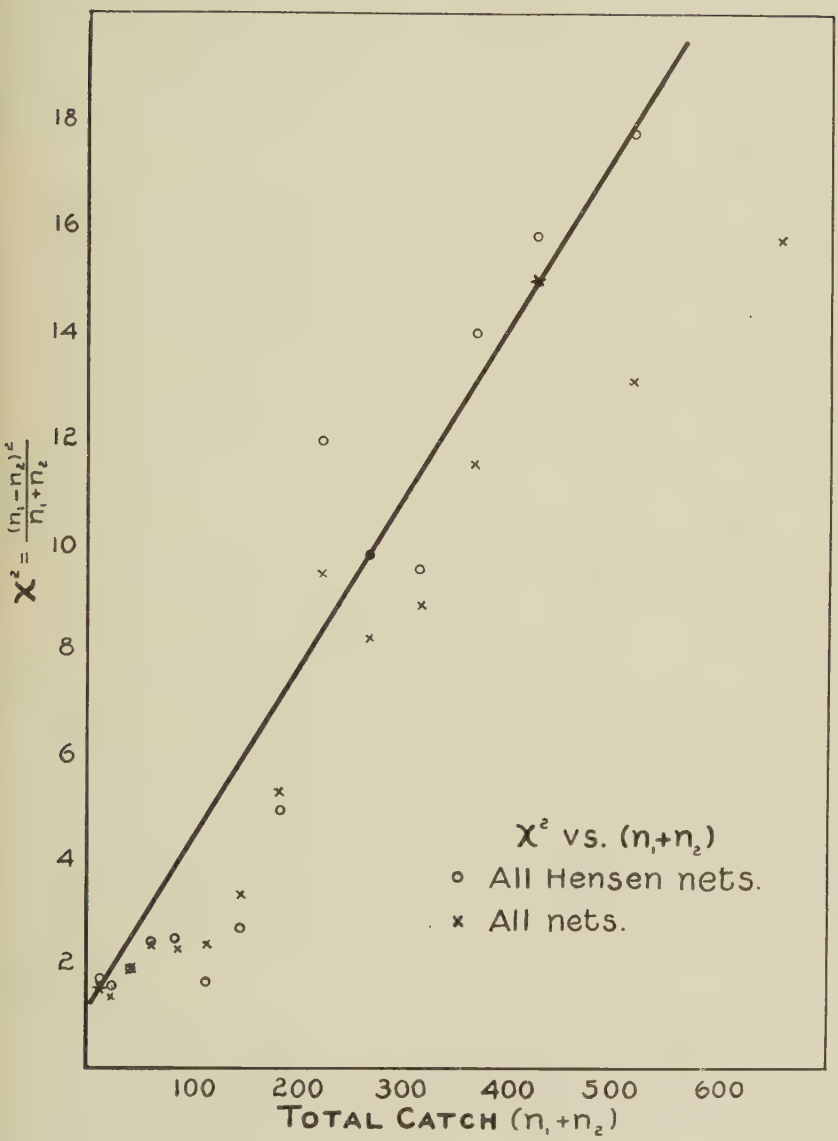

Fig. 1. Distribution of mean values of χ^2 for hauls of varying size.

The last expression, we may observe, implies that for large hauls, the relative accuracy of a single haul will approach about 22.5 %[2]).

[2]) We have chosen to express relative accuracy in terms of the ratio of standard deviation to mean. If the ratio of probable error to mean is preferred, our figures for percentage accuracy should be multiplied by 0.6745. We are unable to see any advantage in the use of the probable error.

In cases where more than one haul has been made at a station, the accuracy with which the mean is known is given by the familiar formula

$$\sigma_m = \frac{\sigma}{\sqrt{N}} \tag{6}$$

where σ_m is the standard deviation of the mean, σ the standard deviation of a single haul, and N the number of hauls. Thus if we have a single haul which has given 100 organisms, the relative accuracy attaching to this is about $\pm$ 24.6 %. If we had two such hauls, our relative accuracy would be increased to about $\pm$ 17.3 %.

All that has been said thus far applies to complete counts. If only a fraction of the haul is counted, it is clear that an allowance will have to be made for variability arising from laboratory sampling. If we actually count a fraction p of the total catch, our estimate of the total will be

$$n' = \frac{c}{p}$$

where c is the number counted. Now a number of such estimates made on a single haul will have standard deviation

$$\sigma_{n'} = \frac{\sigma_c}{p} \; ;$$

but we have to take account also of the variability of the hauls themselves. As shown in the appendix, this results in an expression

$$\sigma_{n'} = \frac{1}{p}\sqrt{K^2c^2 + c} \tag{7}$$

for the standard deviation of n'; and for the coefficient of variation of our estimate we have

$$\frac{\sigma_{n'}}{n'} = 100\sqrt{K^2 + \frac{1}{c}} \; . \tag{8}$$

We observe that this expression is of exactly the same form as that previously obtained for the case where the whole catch was counted, except that on the right-hand side the number actually counted appears.

We may therefore conclude that it is useless to count more than such a number of organisms as will make the fraction $\frac{1}{c}$ small relative to K^2. In practice, if K^2 is, say, 0.05, a count of 100 organisms gives $\sigma_{n'}/n' = 0.245$, while a count of 1000 reduces $\sigma_{n'}/n'$ only to 0.226. It therefore appears useless to increase the number counted of a particular type much above 100.

It may equally be observed that if the number counted falls much below 100, the relative accuracy rapidly decreases. For the particular

value $K^2 = 0.05$, we have calculated Table III, both for single hauls and for paired hauls. In the case of paired hauls, the "number counted" is the mean of the separate counts.

To avoid misconceptions, we may emphasize that the particular value $K^2 = 0.05$ which we have chosen is not to be regarded as a universal constant. We have chosen it because it seems to give a reasonable fit to the data available to us; but we have no doubt that its value will vary from one worker to another, and from one set of conditions to another.

Table III.

Number counted	Coefficient of variation of estimated catch, single hauls	Coefficient of variation of estimated catch, paired hauls
1	102.5	72.5
5	50.0	35.3
10	38.8	27.4
25	30.0	21.2
50	26.5	18.7
75	25.2	17.8
100	24.5	17.3
∞	22.4	15.8

Summary.

The published data have been examined with a view to determining the sampling variability inherent in the use of plankton nets. The dispersion found is greater than can be attributed solely to random dispersal of the organisms in the medium. It is found that if variability is assumed to arise from two sources, (a) random dispersal of organisms and (b) variations in volume of medium sampled, the observed results are reasonably well accounted for. On this assumption it is shown that a limit to the precision of estimate is set by the relative variability of the volume sampled. As a corollary, it appears that it is useless to increase the count of organisms of any particular type much beyond 100.

Appendix
Derivation of Formulae.

1. Poisson distribution.

Assume plankton organisms of some definite type distributed at random with a mean density M. Let the volume of one of these organisms be v, and let the total volume sampled be V. Then this total volume may be divided into $N = V/v$ units of volume. The probability that a particular one of these units shall be a plankton organism is then

$$p = Mv = \frac{MV}{N}$$

The probability of catching exactly n organisms is

$$P(n) = \frac{N!}{n!\,(N-n)!}\,p^n\,(1-p)^{N-n} = \frac{N!}{n!\,(N-n)!}\left(\frac{MV}{N}\right)^n\left(1-\frac{MV}{N}\right)^{N-n} \quad (1)$$

Now if N is large compared with MV, so that p is small, a close approximation to (1) is given by

$$P(n) = \frac{e^{-MV}\,(MV)^n}{n!} \quad (2)$$

This is the well-known Poisson exponential limit to the binomial.

The mean and standard deviation of a population distributed according to (2) are:

$$\text{mean} = m = MV$$

$$\text{s. d.} = \sigma = \sqrt{MV}$$

In practice, we have only samples, and we wish to know whether they might reasonably have been drawn from a population distributed according to the Poisson law. This problem has been analysed by Fisher, Thornton, and MacKenzie (1922), whose treatment we shall follow here.

Consider k samples, of sizes $n_1, n_2, \ldots, n_k$, of which the mean is $\bar{n}$. The probability of obtaining such a series from a population distributed according to (2) is

$$P(n_1, n_2, \ldots n_k) = \frac{e^{-kMV}\,(MV)^{k\bar{n}}}{n_1!\,n_2!\,\ldots n_k!} \quad (3)$$

This may also be written

$$P(n_1, n_2, \ldots n_k) = \frac{e^{-kMV}\,(kMV)^{k\bar{n}}}{(k\bar{n})!} \cdot \frac{(k\bar{n})!}{n_1!\,n_2!\,\ldots n_k!\,(k)} \quad (4)$$

in which the first factor on the right is the probability of obtaining a set of k samples having a mean $\bar{n}$, and the second factor is the probability that k samples with a mean $\bar{n}$ shall have the values $n_1, n_2, \ldots n_k$ actually observed. That is,

$$P(n_1, n_2, \ldots n_k) = P(\bar{n}) \cdot P_{\bar{n}}(n_1, n_2, \ldots n_k) \quad (5)$$

$$P(\bar{n}) = \frac{e^{-kMV}\,(kMV)^{k\bar{n}}}{(k\bar{n})!} \quad (6)$$

$$P_{\bar{n}}(n_1, n_2, \ldots n_k) = \frac{(k\bar{n})!}{n_1!\,n_2!\,\ldots n_k!\,(k)^{k\bar{n}}} \quad (7)$$

Now we may observe, first, that from (6) it follows that our best estimate of MV is given by $\bar{n}$; and second, that the probability of a given partition of an observed $\bar{n}$ is independent of the value of MV. Now the quantity

$$\chi^2 = \frac{1}{\bar{n}} \mathrm{S}\ (n-\bar{n})^2 \tag{8}$$

is a measure of the departure from equipartition of the observed values n_1, $n_2 \ldots$; and the distribution of χ^2 is known, and depends only on the number of degrees of freedom. Tables giving the probability of occurrence of values of χ^2 for different numbers of degrees of freedom have been published (Pearson, 1914; Fisher, 1925). Further, the χ^2 distribution has the property that the sum of a number of χ^2 values is distributed as χ^2, with degrees of freedom equal to the sum of the degrees of freedom of the components.

This latter point is of great importance to us, because in practice it is difficult to obtain more than a limited number of parallels from any one locality. The additive property of χ^2 enables us to combine results obtained by sampling in different localities. We can thus test whether it is reasonable to suppose that a series of sets of parallels have been drawn under Poisson conditions, the Poisson parameter being supposed variable from set to set, though constant within each set.

Actually, we deal here with sets of two parallel hauls. The formula for χ^2 then simplifies to

$$\chi^2 = \frac{(n_1 - n_2)^2}{n_1 + n_2} \tag{9}$$

and each pair contributes one degree of freedom.

If we have a large number of such χ^2 values, we may determine whether their frequency distribution agrees satisfactorily with the theoretical distribution. For this purpose it is convenient to set class-limits such that the theoretical probability of each class is equal — say 1/10.

2. Effects of varying volumes.

So far we have assumed the volume of water sampled constant for each haul. Now clearly variation from one station to another will not affect our problem, provided the volume sampled remains the same for both the members of a pair of parallels; but at a single station differences in volume between the parallels will be of importance. Our treatment can be extended to cover this case as follows:

Suppose M and V are defined as before; but set
$\mathrm{P}(\mathrm{V})d\mathrm{V}$ = probability that V lies between V and $\mathrm{V} + d\mathrm{V}$.

Let $\mathrm{P}_v\ (n)$ = probability that a sample of volume V shall contain n organisms.

Then

$$P(n) = \int_0^\infty P(V)\, P_v(n)\, dV$$

$$P_v(n) = \frac{e^{-MV}(MV)^n}{n!}$$

Write further:

$E(n)$ = mathematical expectation of n

$$= \sum_{n=0}^{\infty} n\ P\ (n)$$

Then

$$E(n) = \sum_{n=0}^{\infty} n \int_0^\infty P\ (V)\ \frac{e^{-MV}(MV)^n}{n!}\ dV$$

$$= \int_0^\infty P\ (V) \sum_{n}^{\infty}{}_0\ \frac{ne^{-MV}(MV)^n}{n!}\ dV$$

$$\int_0^\infty P\ (V)\ MV\ dV$$

$$= M\ E(V)\ . \tag{10}$$

We require further, to obtain the standard deviation of n, the value of $E(n^2)$.

$$E(n^2) \quad Sn^2P(n)$$

$$= \int_0^\infty P\ (V)\ Sn^2\ \frac{e^{-MV}(MV)^n}{n!}\ dV$$

$$= M \int P\ (V)\ V dV + M^2 \int P\ (V)\ V^2 dV$$

$$= ME\ (V) + M^2E(V^2)\ . \tag{11}$$

Now the standard deviations of n and V are given by

$$\sigma_n^2 = E(n^2) - E^2(n)$$

$$\sigma_v^2 = E(V^2) - E^2(V)$$

So that, substituting in (11) and simplifying, we have

$$\sigma_n^2 = ME(V) + M^2\ \sigma_v^2$$

$$\sigma_n^2 = E(n) + E^2(n)\ \frac{\sigma_v^2}{E^2(V)} \tag{12}$$

In practice we do not know $E(n)$ or σ_n, but have to estimate them from the sample values. Now it may be shown that our best estimates of these quantities are given by

$$\bar{n} = \frac{S(n)}{k} \qquad = \text{estimate of } E(n)$$

$$s_n^2 = \frac{S(n-\bar{n})^2}{k-1} = \text{estimate of } \sigma_n^2$$

For pairs of samples these become

$$\bar{n} = \frac{n_1 + n_2}{2} \tag{13}$$

$$s_n^2 = \frac{(n_1 - n_2)^2}{2} \tag{14}$$

Writing

$$\chi^2 = \frac{s_n^2}{\bar{n}} = \frac{(n_1 - n_2)^2}{n_1 + n_2}$$

we have, from (12), substituting $\bar{n}$ for $E(n)$,

$$\chi^2 \quad 1 + \bar{n} \frac{\sigma_v^2}{E^2(V)} \tag{15}$$

We may therefore expect that the mean value of χ^2 for given values of $\bar{n}$ will be a linear function of $\bar{n}$, having an intercept 1 at $n = 0$ and a slope $\frac{\sigma_v^2}{E^2(V)}$.

We are basically interested in the relative accuracy of our hauls, which is given by

$$\frac{\sigma_n}{E(n)}.$$

From (12), (13) and (14) we have

$$\frac{s_n}{\bar{n}} = \sqrt{\frac{1}{\bar{n}} + \frac{\sigma_v^2}{E^2(V)}} \tag{16}$$

which indicates that a limit to our accuracy, regardless of the value of $\bar{n}$, is set by the variation in sample volume.

3. Estimates from fractional counts.

So far we have dealt entirely with total catches. If the total is estimated by counting a fraction p, we may proceed as follows.

Let c be the actual number counted. Then

$$P(c) = S_n \; P(n) P_n(c) \tag{17}$$

were $P_n(c)$ is the probability that our count shall show c organisms if the true total catch is n.

Now

$$P_n(c) = \frac{n!}{c!\,(n-c)!}\, p^c (1-p)^{n-c} \tag{18}$$

And

$$E(c) = S_c \; cP(c) = S_n \left\{ P(n) \; S_c \; cP_n(c) \right\}$$

It may readily be shown that

$$S_c \; cP_n(c) = np$$

and

$$S_c \, c^2 P_n(c) = n^2 p^2 + npq \, .$$

So that we have

$$E(c) = pE(n) = pME(V) \tag{19}$$

Further,

$$\begin{aligned} E(c^2) &= p(1-p)E(n) + p^2 E(n^2) \\ &= p^2 M^2 \sigma_v^2 + p^2 M^2 E^2(V) + pME(V) \\ \sigma_c^2 &= E(c^2) - E^2(c) \\ &= p^2 M^2 \sigma_v^2 + pME(V) \, . \end{aligned} \tag{20}$$

In this expression for σ_c^2 we may substitute for M our best estimate of it, namely $\frac{c}{pE(V)}$, when we have

$$\sigma_c^2 = c + c^2 \frac{\sigma_v^2}{E^2(V)} \tag{21}$$

Now write

$$n' = \frac{c}{p}$$

as our estimate of the total catch. Then

$$\sigma_{n'} = \frac{\sigma_c}{p} = \frac{1}{p} \sqrt{c + c^2 \frac{\sigma_v^2}{E^2(V)}} \tag{22}$$

And for the coefficient of variation of n' we have

$$100 \, \frac{\sigma_{n'}}{n'} = 100 \sqrt{\frac{1}{c} + \frac{\sigma_v^2}{E^2(V)}} \tag{23}$$

$\frac{\sigma_v^2}{E^2(V)}$ is the quantity which we have called K^2 in the text.

4. The assumption of random distribution.

Criticism might be directed at our assumption that the distribution of organisms is random. The assumption is admittedly without direct observational support; and no conclusive answer is possible to an argument that non-randomness in the distribution may account for the variations between hauls.

It may, however, be observed that if such non-randomness is an important factor, we should expect to find differences in the variability of different types of organisms. Now the E.-S. data, based entirely on fish eggs, do not differ appreciably from the Künne data, in which fish eggs form only a part of the total. Further, it is possible to analyse the Künne data by types of organism.

In this analysis we have used the equation

$$\chi^2 = 1 + \bar{n}\ K^2$$

in the following manner. For each type of organism we have summed the values of χ^2 observed, and we have summed the total organisms caught. We have then computed a theoretical value of the summed χ^2 from the equation

$$S(\chi^2) = N + K^2\, S(\bar{n})$$

when N is the total number of pairs of hauls. Table IV gives the values of $S(\chi^2)$ observed and calculated, using $K^2 = 0.05$.

It will be observed that there are rather large differences between the observed and calculated values. These discrepancies arise, however, very largely from the few hauls giving very large numbers of organisms. If we omit hauls with $\bar{n} > 500$ (of which there are 17) we obtain a considerably closer agreement, as shown in the second part of Table IV. In our opinion this agreement is close enough to justify our use of the assumption of random distribution.

Table IV.

$S(\chi^2)$ by types of organisms.

	Using all pairs				Omitting pairs with $\bar{n} > 500$			
	Number of pairs	$S(\chi^2)$ obs.	$S(\chi^2)$ calc.	Ratio obs: calc.	Number of pairs	$S(\chi^2)$ obs.	$S(\chi^2)$ calc.	Ratio obs: calc.
Small Medusae	89	482.78	905.82	0.53	83	392.40	484.42	0.81
Ctenophores	15	37.06	40.38	0.92	15	37.06	40.38	0.92
Tomopteris	8	38.92	43.25	0.90	8	38.92	43.25	0.90
Calanus	82	387.95	478.50	0.81	77	153.51	280.15	0.55
Decapod Larvae	84	732.15	482.00	1.52	82	415.48	388.05	1.07
Sagitta	52	179.46	402.18	0.45	48	160.18	140.85	1.14
Fish Eggs	41	201.20	207.80	0.97	41	201.20	207.80	0.97
Fish Larvae	37	147.16	85.88	1.72	37	147.16	85.88	1.72

Literature Cited.

Berkson, J., Magath, T. B., and Hurn, M. 1935. Laboratory standards in relation to chance fluctuations of the erythrocyte count as estimated with the hemocytometer. J. Am. Stat. Ass., **30**:414-426.

Fisher, R. A. 1925. Statistical methods for research workers. Edinburgh.

Fisher, R. A., Thornton, H. G., and MacKenzie, W. A. 1922. The accuracy of the plating method of estimating the density of bacterial populations. Ann. Appl. Biol. **9**:325-359.

Gardiner, A. C. 1931. The validity of single vertical hauls of the international net in the study of the distribution of the plankton. J. Mar. Biol. Ass., N. S. **17**:449-472.

Gardiner, A. C., and Graham, Michael. 1925. The working error of Petersen's young fish trawl. Great Britain, Ministry of Agriculture and Fisheries, Fishery Investigations, Series II, Vol. VIII, No. 3, 8 pp.

Hensen, V. 1887. Über die Bestimmung des Planktons. 5. Ber. Komm. wiss. Unt. deut. Meer., 1-108.

Herdman, W. A., 1921. Variation in Successive Vertical plankton hauls at Port Erin. Proc. and Trans. of the Liverpool Biological Society, **35**:161-174.

Lohmann, H. 1903. Neue Untersuchungen über den Reichthum des Meeres an Plankton und über die Brauchbarkeit der verschiedenen Fangmethoden. Wiss. Meeresunt., Kiel, N. F. **7**:1-88.

Pearson, K. 1914. Tables for Statisticians and Biometricians. London.

Sources of Data.

Ehrenbaum, E. 1908. Wiss. Meeresunt. Abt. Helgoland, N. F. **8**:201-270.

Ehrenbaum, E. and Mielck, W. 1909. *Ibid.*, **9**:143-176.

Ehrenbaum, E. and Strodtmann, S. 1904. *Ibid.*, **6**:57-126.

Strodtmann, S. 1906. *Ibid.*, **7**:133-216.
1908. *Ibid.*, **8**:177-189.
1918. *Ibid.*, **14**:29-95.

Künne, Cl. 1929. Rapp. Cons. Int. Expl. Mer., **59**:1-37.
1933. *Ibid.*, **83**:1-35.

The "Lowestoft Photometer".

By

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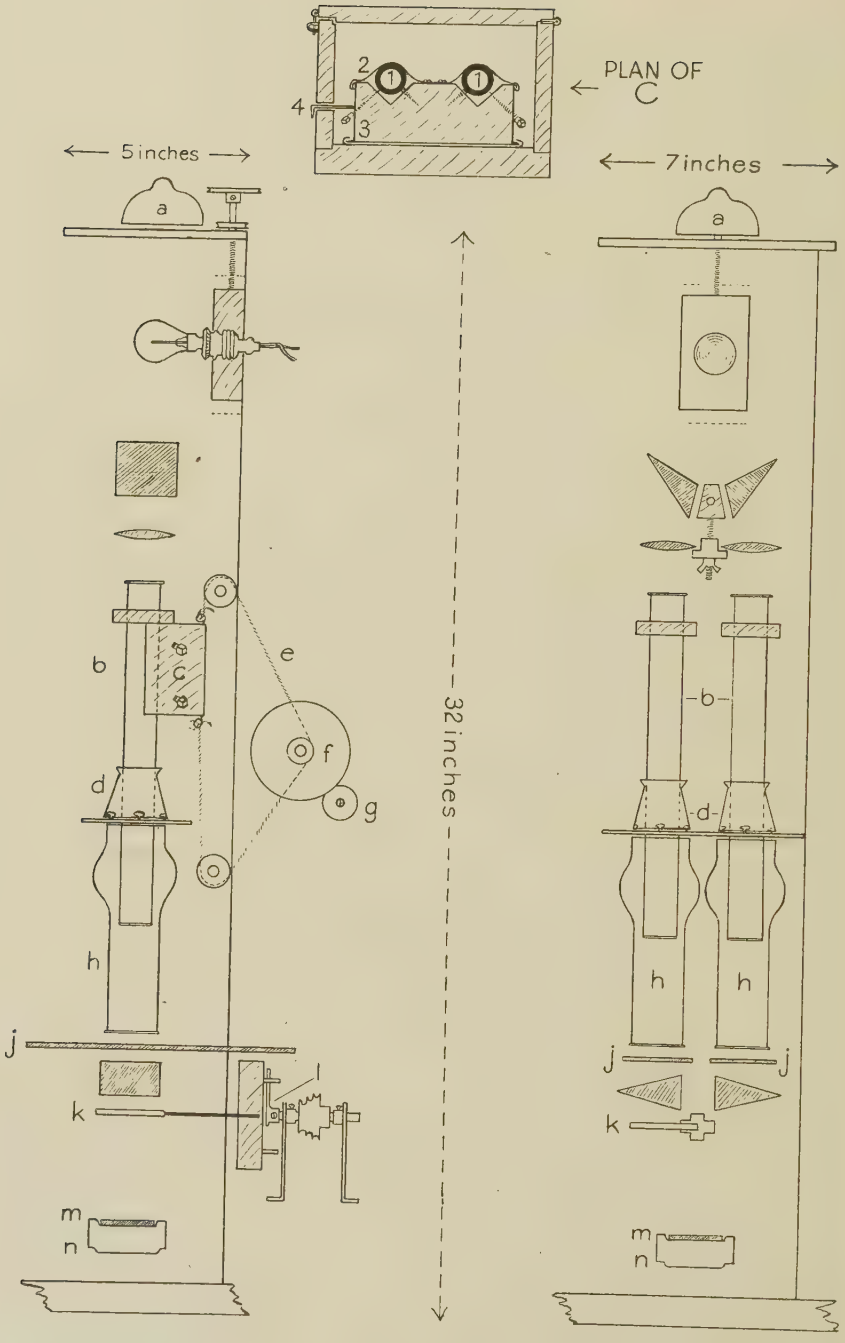
THIS instrument has been made to meet the need of an impersonal method of determining phosphate, that can be used at sea under ordinary conditions. After one year's work bringing the samples ashore, we were not satisfied as to keeping, nor as to our colour judgement immediately after a sea trip, such as is required in using the Atkins-Denigés method. In 1935 the writer saw Drs. Cooper and Atkins and Mr. Harvey at Plymouth and received much good advice about the methods. Mr. H. C. Gilson, of the Sir John Murray Expedition and Cambridge, was also there, and he demonstrated a method in which a light beam was passed through an absorption vessel to a selenium cell and the phosphate value was read on a galvanometer, which had been calibrated by standard solutions. The difficulty that had still to be surmounted was the natural colour and turbidity of sea water. In regard to this, Mr. Harvey had an optically balanced apparatus, for visual determination, and discussion of the matter with colleagues at Lowestoft led to the attempt now described, which combines Gilson's and Harvey's methods. In addition to the help and advice of colleagues and Mr. A. C. Gardiner of the Metropolitan Water Board staff, special mention should be made of the skill of Messrs B. G. Clarke, H. Stokes, and W. Johnston, of the Fisheries Laboratory staff, in surmounting difficulties in details. The only extraordinary parts are the upper absorption glasses, and the galvanometer. We have a reasonable quotation for the glasses from a firm in London. The galvanometer was recently designed for use at sea by the Admiralty Research Department and we are much indebted to them for the loan of it, and for advice. A London instrument maker is to supply one.

The drawings of front and side elevation and the photograph show the construction and principle. In use we first fill the glasses with plain water, always guarding against air bubbles, and move the graded



Side Elevation.

Front Elevation.

Fig. 1.

screens until the galvanometer reading is the same, whichever light track is working the cell, which is always covered with Wratten red filter No. 29. This we call "compensation", for optical faults, and preliminary tests are: (1) that the compensation shall be the same whatever the position of the carriage that carries the upper glasses and the scale pointer, (2) that the compensation shall be unaltered by removal and replacement of all four glasses. In case of failure of these tests it is necessary to adjust the alignment screws on the carriage. This adjustment is usually necessary if the upper glasses have to be replaced by new ones. The present instrument will fulfil the tests over most of its range. Using, as we do, a standard of 200 mg. per cubic metre, the photometer should be accurate for any value of less than 40 mg. Phosphate is rarely over 40 in the Southern North Sea. Results of tests are given below.

After compensation, standard phosphate, 200 P_2O_5, with reagents, is put in the left lower glass, distilled water in the right lower, sample plus acid molybdate reagent in the left upper and sample plus the molybdate reagent plus stannous chloride in the right upper. The shutter is driven continuously by a gramophone motor rather faster than 1 cycle per second and the galvanometer spot takes up this motion, so long as the absorption is unbalanced. The carriage with the upper glasses is then moved until, as the point of balance is reached, the induced oscillation of the galvanometer spot ceases and the spot takes up the roll of the ship. This is a very clear end-point, even clearer than the corresponding coming to rest when on land. The same effect

---

Fig. 1. *Key.*

a. compass ventilator.
b. upper glass. 12-inch Nessler glasses cut to 10-inch internal and sand-blasted inside, fitted with wooden supporting collars. Filled brimming and closed by glass disk. Diameter of beam at base reduced to 11/16-inch by vulcanite washer.
c. carriage with 8 alignment screws. See separate key below.
d. cloth light-trap.
e. corded seaming twine.
f. wheel carrying a worm on which *e* is wrapped so driving *c.*
g. rubber bung for brake.
h. lower glass. Lamp chimney cut and closed with glass disk held by section of bicycle inner-tube smeared with non-setting rubber solution.
j. graded screen made by moving photographic plate slowly in and out of a faint beam of light.
k. moving shutter shaped like a warming pan, with counterpoise beam and pins, which are brass screws with heads filed away, leaving the kerf.
l. crank, driven with a rubber band from gramophone motor.
m. Wratten red filter No. 29 in B glass 40 mm. diameter.
n. Weston selenium cell driving galvanometer direct.
(Further details are included at the end of the text.)

Plan of c. Carriage.

1. upper glass in section, held against alignment screws.
2. elastic with corset hook engaging on edge of carriage.
3. screw-driver point running in grooves made of folded brass.
4. indicator point.

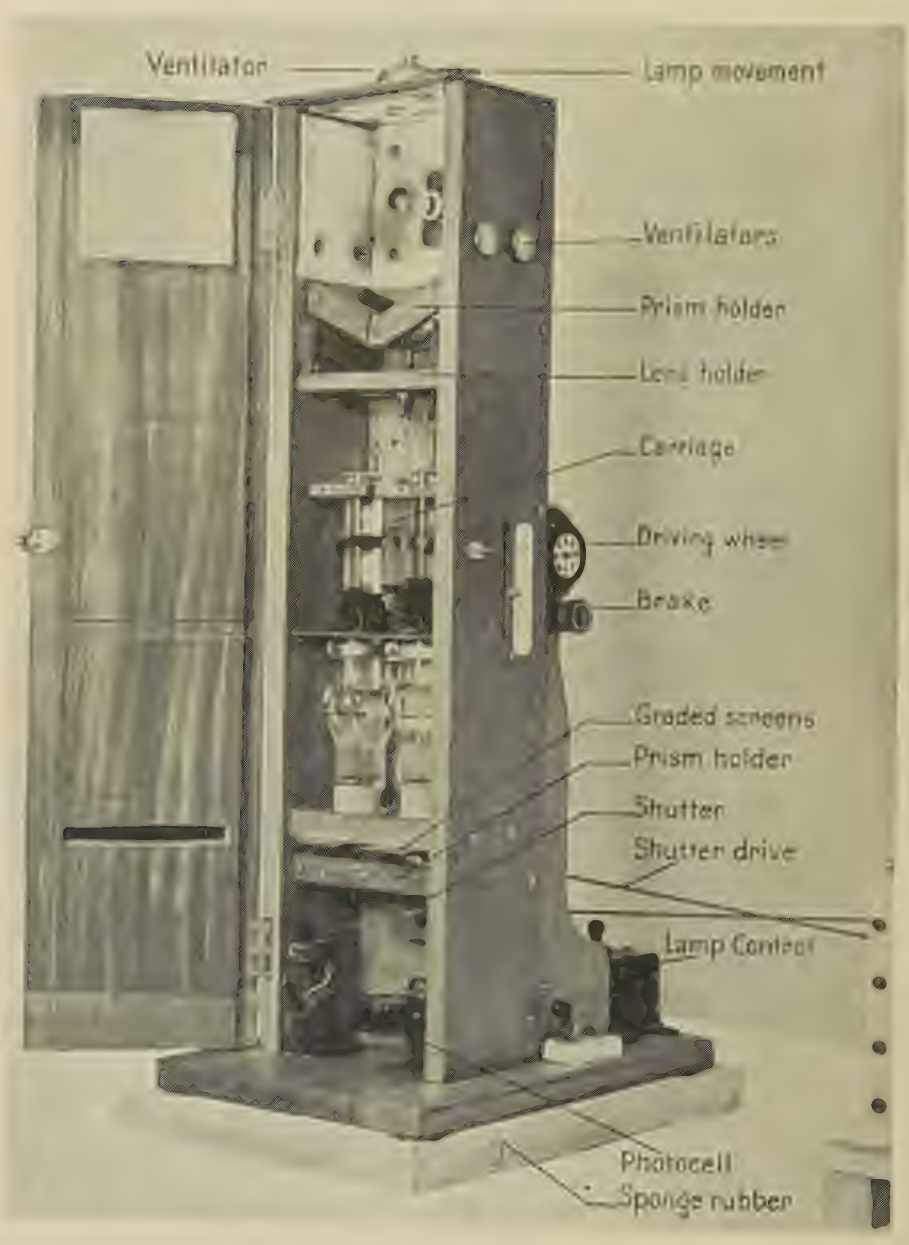


Fig. 2.
See also Key to Fig. 1. The lower glasses are now sheathed in rubber, as far as the bulge.

cannot be had with a good ordinary galvanometer, which moves with the ship all the time.

At the position of balance the pointer shows the height of the lower surface of the liquid in the upper glasses measured from the lower surface in the lower glasses. The scale is outside the instrument and is divided in twentieths of an inch. The height of the liquid in the upper tubes is always 10 inches, so this scale reads milligrammes of P_2O_5, if we assume B a e r's law.

The time taken depends on the weather. Usually we do the five or six samples at the end of a station in about 70 minutes, and the instrument reads to about 1 mg., including any personal error.

However, as we have already noted, the photometer cannot be so accurate above 40, owing to optical defect. Tests have shown that slight differences in the size of openings in washers, in the etching inside the upper glasses, and such things, appreciably affect the accuracy of the present model. We are not satisfied that every possible improvement in this sort of thing has yet been made, but the following record of a test shows the degree of accuracy so far reached. A second test, after some adjustment of the instrument, is recorded in heavy type.

Some borax methylene blue solution was diluted until it approximately matched the blue colour given by standard phosphate 200 mg. Imitation standards were then made up from this solution, so diluted as to be equivalent to various phosphate values, and these were tested in the photometer against the imitation standard 200. The series was carried through twice, two readings each time, after the compensation range had been found to be from 0—38 mg.

	11th February 1936				6th March 1936			
Dilution Value	1st Round				2nd Round			
"5"	5	5	**4**	**5**	5	6	**5**	**5**
"10"	12½	12	**10**	**10**	13	12½	**9½**	**10**
"20"	21	20	**18**	**20**	20	21	**20**	**20**
"30"	31	31	**27**	**28**	31	30	**28**	**29**
"40"	39	39	**38**	**37**	39	39	**37**	**37**
"50"	49	47	**43**	**43**	48	47	**44**	**43**

There should be no difficulty in at least maintaining this standard of accuracy, which is sufficient for ordinary purposes.

We have not yet had an opportunity of redetermining the salt error.

The cost can only be estimated, because we made this model ourselves. We have, however:— upper tubes and duplicates 16/—, 4 cheap prisms 4/—, masked with insulating tape, 24-watt lamp in "Small Edison Screw" holder 4/—, spectacle lenses 2/—, lamp chimneys 1/—, photographic plates for making screens 1/—, selenium cell £ 4, Wratten filter No. 29 in B glass 10/—, toy engineering parts etc. say £ 1, brass parts say £ 1, 5-ohm 4-amp. variable resistance for control of lamp £ 1, gramophone motor £ 1/10/—, 12-volt car battery for lamp £ 5, galvanometer, sensitivity 45 mm. per micro-amp., achieves deflexion in about

half a second, £ 35, protective 10,000-ohm variable shunt (radio volume-control) 3/—. This makes about £ 50 for components, of which the galvanometer is the most expensive. All important wood in the photometer is well-seasoned teak, actually old fish-measuring board, well coated with shellac and wax before assembling. If satisfactory wood can be had, the making should not cost more than £ 10, perhaps £ 5, but instrument makers would, properly, have expensive improvements and would despise toy engineering components.

We think the instrument will also serve for turbidity, phytoplankton by colour, and other chemical determinations.

Stock Replenishment and Fishing Intensity in the Haddock of the North Sea.

By

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THE fluctuations which have taken place in the amplitude of recruitment of stock by new haddock broods within the North Sea in recent years were reported upon, together with those of other haddock fishing grounds, to the special meeting on fluctuations held by the International Council for the Exploration of the Sea on 11th May 1936 (Raitt, 1936).

The present paper deals in more detail with the one area, the North Sea, and was presented before the Northern North Sea Committee of the International Council on 13th May 1936.

Assessments of the relative strengths of the different age-groups of haddock in the North Sea from 1919 to 1927 were published by Thompson, 1929. Similar stock analyses have now been made for the period 1928 to 1935. Both sets of statistics are based upon the average numbers of haddock taken by the Scottish Fishery Research Ship "Explorer" per 10 hours' fishing, the gear in use being an ordinary otter trawl the cod-end of which is fitted with an auxiliary covering of small-mesh shrimp netting.

It has been found that over the 20 years 1916 to 1935 there occurred in the haddock of the North Sea six prolific stock replenishment seasons, 1920, 1923, 1926, 1928, 1931, and 1935, seven poor ones, 1917, 1921, 1922, 1927, 1930, 1932 and 1934, and seven of intermediate order, 1916, 1918, 1919, 1924, 1925, 1929, and 1933.

Definite first year values are assignable from the data to all age-groups from 1919 to 1934 inclusive. The extent to which recruitment varied over that period is strikingly shown when these values are graphed as in Fig. 1. Replenishment fluctuated in the proportion of as much as 60 to one. The especially prolific 1928 brood was greater by that ratio than the especially poor one of 1922.

Highly successful broods occurred at intervals mostly of two years, never consecutively. Prior to 1920, however, there would appear to have been a sequence of four years none of which was of particularly dominant order, and following 1931 there intervened two especially poor years and one intermediate before the next outstanding brood, that of 1935.

The effect of these brood fluctuations upon commercial catches is readily recognizable when comparison is made with statistics as to market landings. Data are collected continuously from all British vessels landing catches at fishing ports in England and Scotland. This material is issued by the Ministry of Agriculture and Fisheries in the form of monthly charts giving the productivity of each statistical square in the North Sea. Separate charts are issued for "large" haddock, "small" haddock, and for both combined.

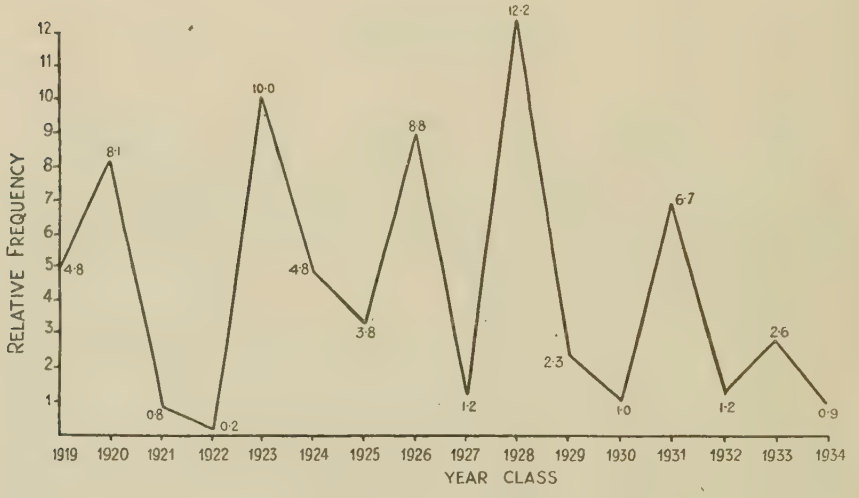

Figure 1. The Relative Numerical Values of North Sea Haddock Broods in the First Year of Life, 1919—1934.

When the total catches of "small" haddock per annum are compared with the research vessel data as to the first year frequencies of the broods of two years earlier, that is the landings of 1924 being compared with the brood of 1922 and so on, as illustrated in Fig. 2, remarkably close agreement is found. From 1922 to 1934 the landings of "small" haddock from the North Sea rose and fell in step with the rise and fall in the abundance of the new broods of two seasons previously.

Fig. 2 emphasizes the usefulness of these stock analyses from the practical viewpoint of yield prediction. For some years now there has been published in the Annual Report of the Fishery Board for Scotland a forecast of the probable yield of the North Sea haddock fishery based upon evaluations of brood strengths from first year onwards.

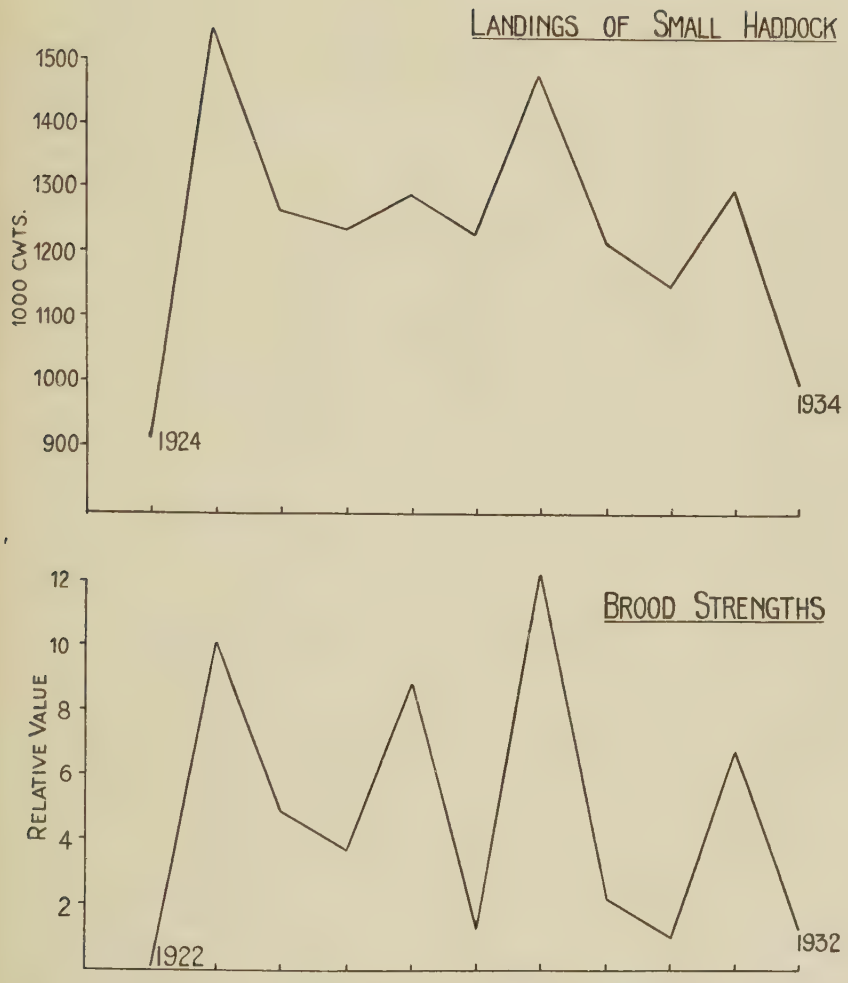

Figure 2. Comparison of Total British Landings of Small Haddock, 1924—1934, with First Year Brood Strengths, 1922—1932.

They have been highly successful and are being followed up and perfected. At the present time, for example, the good brood of 1931 being into its sixth year and practically fished out, 1932 having been of inferior order, 1933 only intermediate, 1934 also inferior, and 1935 not yet under the influence of commercial fishing operations, poor catches are being made by North Sea vessels, as was anticipated more than twelve months ago. The upgrowth of the strong 1935 brood, however, will greatly improve the general productivity of the area in due course, probably commencing towards the close of the present year.

Let us now consider the total catches per annum of "large" haddock

Figure 3. Total British Landings of Large Haddock, 1924—1934.

from the North Sea over the same period of years, as illustrated in Fig. 3. In spite of the occurrence of outstandingly successful recruitment of stock in 1920, 1923, 1926, 1928, and 1931, which was duly reflected in the catches of "smalls", the landings of "large" haddock steadily declined.

A similar trend has long been noticed in the haddock landings at Aberdeen, the statistics of which are given in the 54th Annual Report of the Scottish Fishery Board (1935, p. 27) in the four categories "small", "medium", "large", and "extra large". There has taken place over the past twelve years a progressive decrease in the ratio of "large" to "small" haddock in the catches. As regards the actual proportions of the different categories in the catches it may be mentioned that from 1931 to 1935 "smalls" averaged 84 % of the total landings, "mediums" 8 %, "large" 6 %, and "extra large" 2 %.

That the progressive decline in the stock of large haddock in the North Sea is due to the cumulative effect of commercial fishing operations is the only possible conclusion.

From his age-group frequency data covering the years 1919 to 1927, Thompson, 1930, gave the mortality rate of a brood of North Sea haddock as being comparatively low up to the third year of life. Thereafter, when it is fully under the influence of the commercial trawl, there is a marked increase which is more or less regularly sustained in later years. On the average, over the period in review,

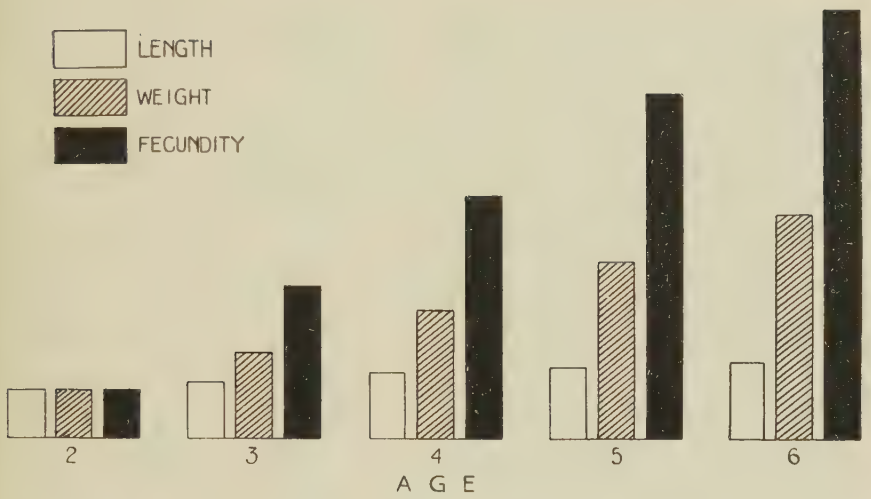

Figure 4. The Increase, with Age, in Length, Weight, and Fecundity, in the Haddock of the North Sea.

for every 100 haddock available for capture in the first year of life, there were 80 available in the second, and 68 in the third, but only 26 in the fourth, 12 in the fifth, 6 in the sixth, 3 in the seventh, and 1 in the eighth. Even in the case of a prolific brood, therefore, an age-group had made its major contribution to the fishery by the end of its third year, and had ceased to be of commercial importance by the end of its fourth. And until the time of the mesh of net and minimum landing size regulations adopted by Britain in 1933, the position was becoming worse, as shown by the fall in the landings of large fish in Fig. 3.

These figures may be usefully linked with the results of an investigation of the fecundity of the haddock which the writer completed a year or two ago (R a i t t, 1932).

The reproductive powers of a species must be regarded as one of its most fundamental characteristics being a reflection of the struggle it has had to establish and to maintain its position in the animal kingdom against natural enemies, and all such factors affecting natural mortality rate. Such a characteristic can scarcely be expected suddenly to alter in its extent to counteract the relatively sudden intervention of man in the scheme of things.

As a measure of reproductive power one may take the number of eggs a female haddock is capable of shedding at one spawning time. That has been found to depend upon its size and its age. It is not proposed to recapitulate herein the mathematical details of the investigation. These may be consulted in the full account of the work already in publication. The present study is concerned with certain of its practical applications.

Between the ages of two and three, as illustrated diagrammatically in Fig. 4, while the haddock increases in length on the average only from about 25 to about 30 cm., it practically doubles its weight and increases its egg production three times. Between the ages of two and four, it practically trebles its weight and increases its egg production five times. Between two and five it increases its weight by about four times and its egg production seven times, and between two and six, while it grows on the average only from about 25 to about 40 cm., that is, it less than doubles its length, it increases its weight about five times and its egg production nine times.

A two-year-old female spawner of average size is about 124 gm. in gross weight and produces about 31,000 eggs. A six-year-old spawner of average size is about 586 gm. in gross weight and produces about 278,000 eggs.

By fishing out the bulk of a brood by its fourth year of life we were therefore depriving the area of by far its best spawners. We were forcing the brunt of stock recruitment upon two and three-year-old fish much less well provided by nature to do so.

Further, as a result of the examination of the sex organs of over 12,000 haddock at spawning time, it has been found, as shown in Fig. 5, that only about 10 % of the females of the species mature at the age of two, and 75 % at the age of three. By the age of four, 95 % have ripened, and about 99 % at five. Thereafter, normally, all survivors are spawners.

The male of the species matures rather earlier than the female. About 60 % ripen at the age of two, 95 % at three, 99 % at four, and by the end of the fifth year of life all survivors normally are spawners, that is one year earlier than females.

In addition, therefore, to two and three-year-old female haddock being much inferior egg producers compared with older fish, appreciable proportions of these age-groups are still immature.

According to the latest information available (Davis, 1934) a trawl which conforms to the British mesh regulations of 1933 may begin to retain haddock when they are no more than 14 cm. in length (about 5½ inches) and escape from it is impossible for all individuals of 32 cm. and over (about 12½ inches). Statistics of commercial catches indicate that at a length of about 23 cm. (9 inches) 75 escape for every 25 captured, at about 26 cm. (10¼ inches) 50 escape for every 50 captured, and at about 28 cm. (11 inches) 25 escape for every 75 captured.

A trawl of smaller mesh such as was previously in use on board British trawlers began to take toll of the stock at an even earlier point, and escape from it was impossible for individuals correspondingly less in length. The increase in size of mesh had as its aim a saving of the younger fish. But even with that saving, we are still capturing the species before it is three years old, the average age at which first maturity is reached. The average length of a two-year-old haddock is about ten inches. The minimum landing size is only 9½ inches.

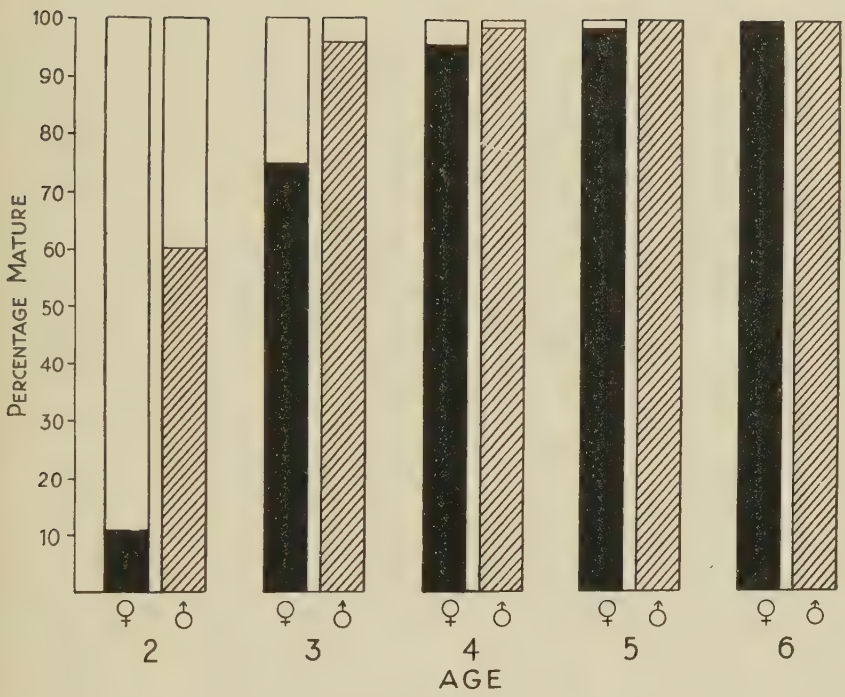

Figure 5. The Proportions of Mature and Immature North Sea Haddock at Different Ages.

As to the effect the British mesh regulations have had on the stock since their imposition in 1933 it is as yet impractical to form judgement. Not only is the time during which they have been operating of very limited extent, but also, over the years 1932, 1933, and 1934, recruitment of stock has been of inferior order and the survival of these year-classes cannot be regarded as an acceptable test. The brood of 1935, however, being of much stronger numerical order should provide suitable comparison with the rates of depletion of former prolific age-groups. As already stated, it should come under the influence of commercial operations towards the close of the present year.

In conclusion, mention may be made of certain investigations which have recently been conducted concerning the growth-rate of the species. Contrary to the belief that haddock growth-rates do not vary appreciably from year to year, considerable variations have been noted in the lengths attained by different broods of North Sea haddock by the end of their first and second years of life. Over the region as a whole, the first year average lengths of the nine broods 1926 to 1934 varied from 14.3 to 17.8 cm. and the second year average lengths of the nine broods 1925 to 1933 varied from 23.2 to 26.1 cm. Both sets of figures show a tendency to increase over the period in review. When the average lengths found for first year fish were correlated with the fall in the

landings of large haddock as graphed in Fig. 3, a correlation coefficient of — .73 was obtained, corresponding to a probability of having arisen by random sampling from uncorrelated material about twice in a hundred trials. In the case of the second year average lengths, the correlation coefficient was —.66, corresponding to a probability of having arisen by random sampling from uncorrelated material about five times in a hundred trials.

In other words, at the same time as the landings of large haddock from the North Sea were steadily falling, indicating increasing fishing out of the older age-groups of the stock, there appears to have been something of an increase in the rate of growth of younger fish. So far no more may be said. Since, however, the question of an optimum point in fishing intensity is involved, the matter is receiving further attention.

Literature References.

Davis, F. M., 1934. "Mesh Experiments with Trawls, 1928—1933." Min. of Agric. and Fish., Fish. Invest., Ser. II, Vol. XIV, No. I, 1934.

Raitt, D. S., 1932. "The Fecundity of the Haddock." Fisheries, Scotland, Sci. Invest., 1932, No. I.

Raitt, D. S., 1932. "The Age Composition of the Haddock Stocks of the Different Fishing Regions of the North-East Atlantic covering the period 1916—1935." Part III of "Age Composition of Haddock in European Waters," Robert S. Clark, Cons. Perm. Intern. p. l'Explor. de la Mer, Rapp. et Proc.-Verb., Vol. 101, 3ème partie, 1936.

Thompson, H., 1929. "Haddock Biology (North Sea)." Cons. Perm. Intern p. l'Explor. de la Mer, Rapp. et Proc.-Verb., Vol. LIV, 1929.

Thompson, H., 1930. "On the Possibility of Effecting and Utilising accurate Estimates of Haddock Fluctuations." Cons. Perm. Intern. p. l'Explor. de la Mer, Rapp. et Proc.-Verb., Vol. LXVIII, 1930.

The Occurrence of Lee's Phenomenon in the Sprat, and the Size-Relation between Fish and Scale.

By

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Material.

SAMPLES of sprats, caught by commercial vessels on the east coast of England, were examined in each of the six fishing seasons from 1929/30 to 1934/35. These samples were caught by two types of gear, sprat drift-nets and stownets[1]), which differ greatly in their selective effect upon the catch. Scales were taken for age-estimation whenever they were obtainable, but from the stownet catches very few were available until the last three seasons, when the sampling technique had been improved.

The samples from all six seasons were combined, and Figure 1 shows the calculated lengths at their 1st, 2nd, and 3rd winter-rings (l_1, l_2 and l_3)[2]) of fish from age-groups I to IV.

It is quite obvious that l_1 is smaller in the older than in the younger age-groups, and this is equally evident in the case of l_2 and l_3. In these sprat samples Lee's phenomenon is very strongly marked.

Examination of the data.

In the first place an attempt was made to correct the *modal* l_1 and l_2 for the size of the fish at the first formation of the scales. The size of the young sprat when scales first appear is given by Jenkins (1902) as 2.5—3.0 cm.; by Lebour (1919/22) as 3.5 cm.; by McIntosh and Masterman (1897) as 2.5—3.3 cm.; and

[1]) Relatively non-selective bag-nets, fished by a vessel at anchor in a strong tide. Drift-nets do not take sprats of the smaller sizes found in stownet catches (Robertson 1936). I have found that in drift-nets the size of sprat taken varies directly with the size of mesh used, in the same manner as in the case of the herring (cf. Hodgson 1927 and 1933).

[2]) Calculated from Lea's formula: $l_1 = \frac{c_1}{V} L$.

by F a g e (1920) as 3.5 cm. when the sprat undergoes metamorphosis. Taking 3.0 cm. as a convenient approximation, the Meek-Fraser-Molander-Lee correction (G r a h a m 1929)[3]) was applied; i. e.

$$l_1' - l_1 = 3 - \left(\frac{v_1}{V} 3\right)$$
$$= 3 - \left(\frac{l_1}{L} 3\right) \quad [4])$$

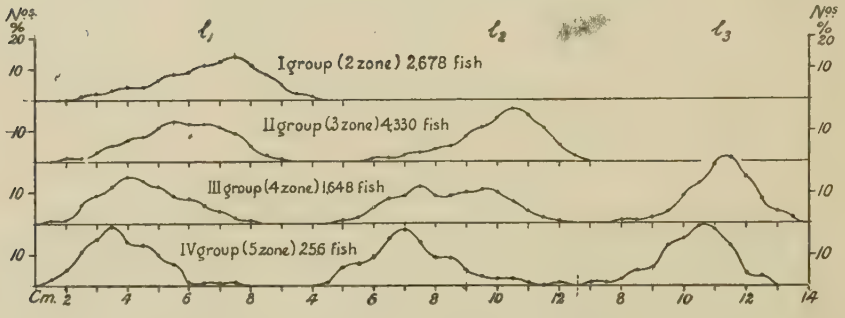

Figure 1. l_1, l_2 and l_3 of age-groups I to IV. Drift-net and stownet samples from the East Coast. Seasons 1929/30 to 1934/35 combined.

where l_1' is the true, and l_1 the uncorrected size of fish at the first winter ring, v_1 the corresponding size of scale, and L and V the definitive sizes of fish and scale respectively.

The following figures give the l_1, l_2, l_3 and l_4 of the combined samples before and after correction by this method: —

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[3]) cf. G r a h a m (1929) p. 39, where $L = A + BV$. Taking $A = 3$ cm.

$L = 3 + BV$

or $L - 3 = BV$

and so $l_1' - 3 = Bv_1$

and hence $\frac{l_1' - 3}{L - 3} = \frac{v_1}{V}$

$l_1' = \frac{v_1}{V}(L - 3) + 3$

but it was assumed that $l_1 = \frac{v_1}{V} L$ (L e a's formula)

therefore $l_1' - l_1 = 3 - \left(\frac{v_1}{V} 3\right)$

[4]) This step is permissible because in this material, by using L e a's proportionating apparatus, l_1 was made to bear the same proportional relation to the observed length L that v_1 did to V on the scale-tracings.

Age-group	Modal l_1	Modal Length (L)	Correction	Corrected l_1'
I	7.6 cm.	11.1 cm.	+ 0.9 cm.	8.5 cm
II	5.5 „	12.2 „	+ 1.6 „	7.1 „
III	4.1 „	12.9 „	+ 2.0 „	6.1 „
IV	3.5 „	13.2 „	+ 2.2 „	5.7 „

Age-group	Modal l_2	Modal Length (L)	Correction	Corrected l_2'
II	10.5 cm.	12.2 cm.	+ 0.4 cm.	10.9 cm.
[5] III	9.7 „	12.9 „	+ 0.7 „	10.4 „
IIIa	7.5 „	12.9 „	+ 1.3 „	8.8 „
IV	7.0 „	13.2 „	+ 1.4 „	8.4 „

Age-group	Modal l_3	Modal Length (L)	Correction	Corrected l_3'
III	11.4 cm.	12.9 cm.	+ 0.3 cm.	11.7 cm.
IV	10.7 „	13.2 „	+ 0.6 „	11.3 „

Age-group	Modal l_4	Modal Length (L)	Correction	Corrected l_4'
IV	12.2 cm.	13.2 cm.	+ 0.2 cm.	12.4 cm.

N.B. *Modes obtained by inspection.*

The correction fails to eliminate the decrease in calculated size in successive age-groups, although it somewhat reduces it, and therefore the normal lag in scale-formation does not go far to explain the occurrence of Lee's phenomenon in this material. Moreover, as in winter the observed modal size of 0-group sprats (whitebait) is known to be about 5 cm. (Robertson 1936), it seems that the application of this correction so increases the calculated l_1 that a considerable discrepancy is introduced.

On the other hand when the correction is applied to *modal* l_2, l_3 and l_4 it does not raise them as high as the observed *modal* lengths of I, II and III-group fish respectively (cf. third column in the foregoing table of l_1). The correction was also applied to the Brightlingsea (stownet) material of Figure 3, and Lee's phenomenon, although much less pronounced than in Figure 1, was likewise reduced but not eliminated. The differences between calculated and observed sizes were, however, less marked.

Since evidence is produced in this paper (cf. page 223) that the relative proportions of fish and scale do not vary in any regular manner with age or size, it is not surprising that the Meek-Fraser-Molander-Lee correction is not very helpful in the case of the sprat, for it is made on the assumption that only the length acquired by the fish *after scale-formation* is proportional to the scale-size. The investigation of its effect is, however, a necessary and almost traditional preliminary to any examination of a case of Lee's phenomenon.

[5]) Bimodal.

The values of l_1, l_2 and l_3 were calculated according to Lea's formula, and the appearance of Lee's phenomenon (i. e. decrease of l_1 with increasing age of fish) must therefore be due to one or more of the following causes: —

1. L (definitive length of fish) being smaller in older than in younger fish.

2. v_1/V being smaller in older than in younger fish, due *either to*

(a) a decrease in v_1 with age —

(i) through actual resorption of scale-tissue, or alternatively

(ii) owing to the better survival or representation in successively older age-groups of fish with small v_1 (and small l_1) and an opposite trend in the case of fish with larger v_1 and l_1,

or to

(b) V (the scale) increasing with age at a rate disproportionate to and greater than that of L (the fish).

The possible cause given in (1) above is highly improbable *a priori* and is in direct conflict with my own observations on the growth of the sprat, based on this same material (Robertson, 1936).

The first explanation suggested in (2a), — reduction of v_1 by resorption of scale-tissue, — is scarcely susceptible to direct proof or disproof, but I have found no evidence in favour of such a process, in spite of considerable practice in the examination of scales for age-estimation and some work on the details of their surface structure (Robertson, 1933). Such resorption might reasonably be expected to leave a visible mark upon the scale surface.

In the Brightlingsea samples mentioned in the following paragraph no marked difference exists between the observed and calculated scale-sizes in the same year-class; neither v_2 nor v_3 appear to diminish with age, and in this case at least it would be quite unwarrantable to assume that any resorption of scale-tissue had occurred.

The second possibility, in (2a), that fish with small v_1 (v_2 and v_3), survive better or are more numerous, and those with larger v_1 are less well represented, in the older age-groups than the younger age-groups, was tested in the case of *stownet* samples obtained from Brightlingsea. Stownet samples are particularly suitable for this purpose as the gear is relatively non-selective. As it was thought best to start with scales and fish of observed and definitive rather than of calculated size, and as 0-group fish are exceedingly scarce in the adult shoals, the actual scale size (V) of I-group (2-zone) fish was compared with the v_2 of II-group (3-zone) fish in the following season. Likewise V of II-group (3-zone) fish was compared with v_3 of III-group (4-zone) fish of a year later. The curves on the left of Figure 2, which gives these results, show that there is *no appreciable diminution* in v_2 or in v_3 as the fish of a particular year-class pass from one age-group to the next.

In view of this it seemed probable that in Brightlingsea stownet samples there would also be no diminution in l_2 and l_3 with increasing age. The curves on the right of Figure 2, which give the fish-sizes corresponding to the scale-sizes on the left, tend to confirm this

assumption. Yet, if all the Brightlingsea stownet samples for the three available seasons are combined, l_1, l_2 and l_3 still show a diminution with increasing age (Figure 3). In this case L e e's phenomeon is much less marked than in Figure 1, the material for which included a very large majority of sprats caught in drift-nets, together with a minority of stownet (Brightlingsea) fish.

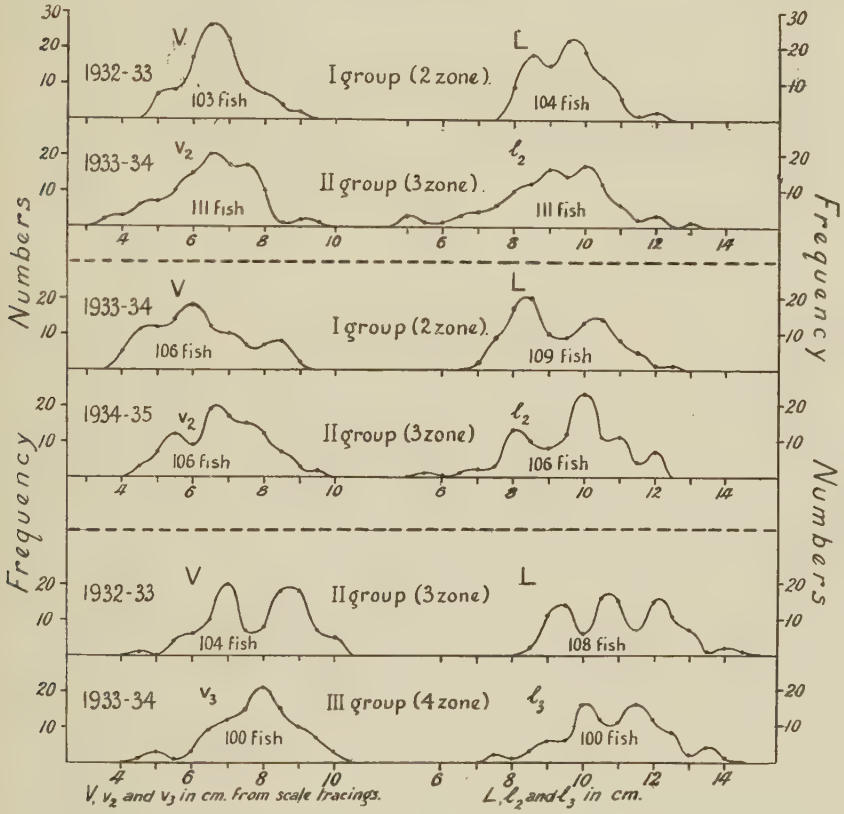

Figure 2. Comparison of v_2 and l_2 and v_3 and l_3 in three different year-classes of Brightlingsea (stownet) fish.

Thus a combination of all the Brightlingsea stownet samples for the three seasons still shows L e e's phenomenon, although it is much less pronounced (Figure 3), but when three different year-classes are examined separately (Figure 2), it is no longer apparent.

The Ratio fish/scale.

There remains the possibility (2b above) that scale-size (V) and fish-size (L) do not increase proportionately, as is usually assumed, but that V increases at a rate exceeding that of L, thereby reducing v_1/V in L e a's formula for the growth of fish and scale ($l_1 = L \cdot v_1/V$).

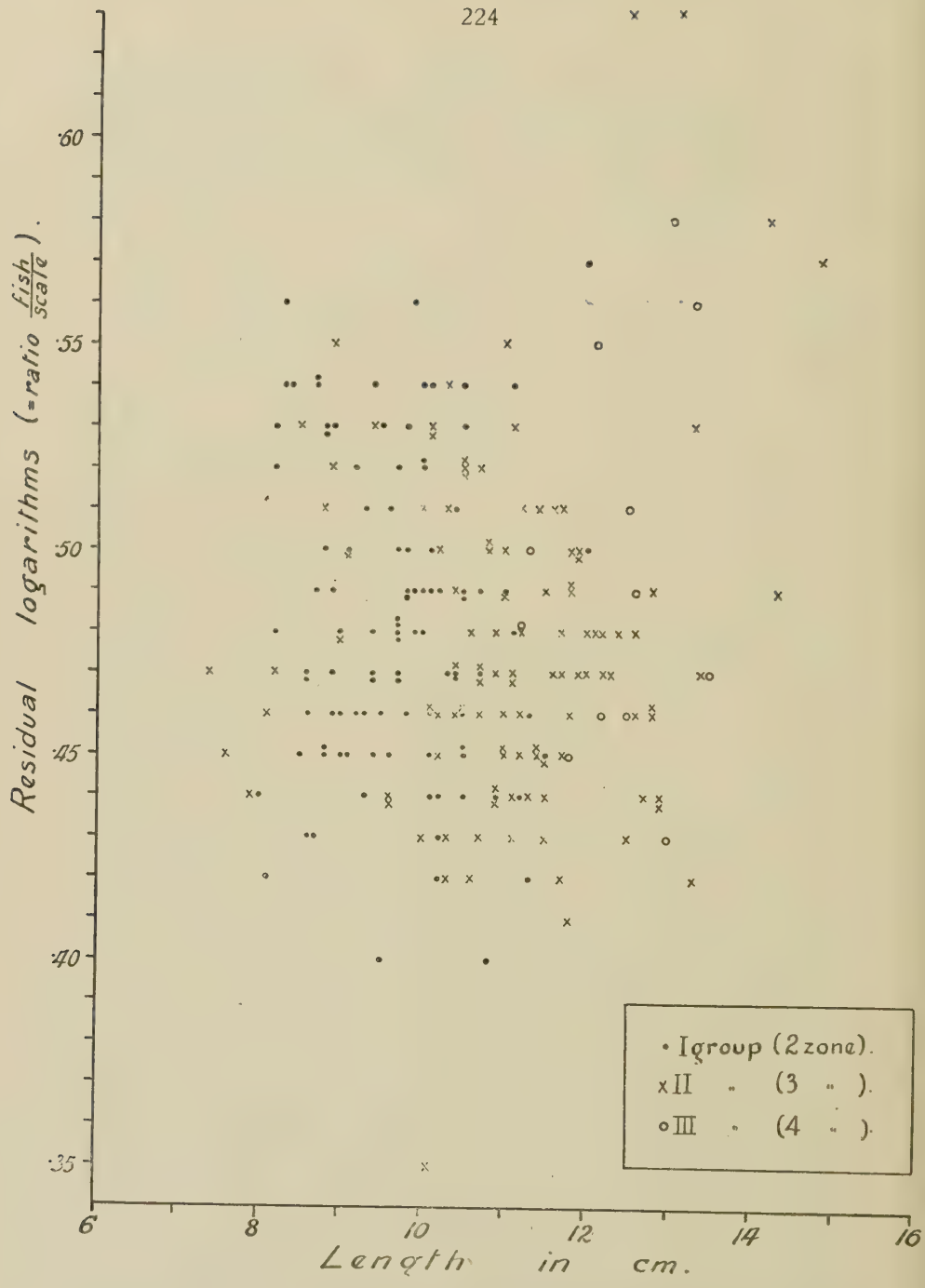

Figure 4. Residual log. (= ratio fish/scale) plotted against length of each fish. Brightlingsea fish of a single year-class during three successive years of their life. Age-groups I to III in seasons 1932/33 to 1934/35 respectively.

In order to test this possibility as thoroughly as possible I used a method devised by Mr. H. J. Buchanan-Wollaston.

Scale[1]) and fish were measured, their logarithms were found, and the residual of log. fish-length minus log. scale-length was obtained for each fish.

The frequency distributions of these residual logs (representing the ratios fish/scale) were compared and submitted to Fisher's χ^2 test in the following manner: —

Pairs of distributions
1. of the same year-class *at different ages.*
2. of fish of the same age *in different years.*
3. *of fish of different age* in the same year.

Table 1 gives the results of these comparisons. A probability (P) of .02 and under is considered to show a statistically significant difference between the members of a pair of distributions.

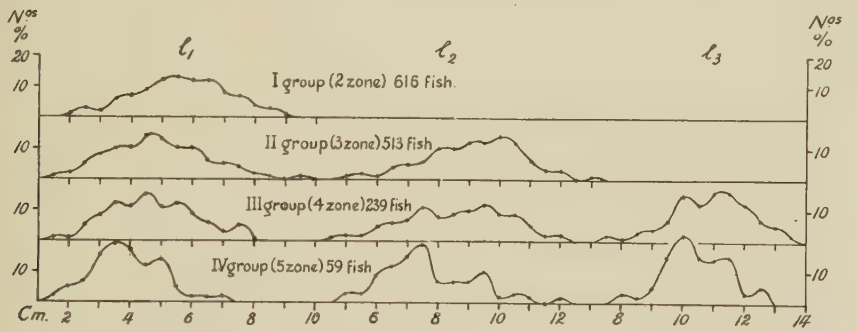

Figure 3. l_1, l_2 and l_3 of age-groups I to IV. Stownet samples from Brightlingsea. Seasons 1932/33 to 1934/35 combined.

It is clear that, with the exception of I-group (2-zone) fish in 1933/34, there is *no significant difference* between the distributions of residual logs in whichever way they are compared. It seems likely that the exception referred to is due to the use of small scales (probably from the tail region[2]), which would give rise to the number of unusually high residual logs which this age-group contained. This age-group was evidently quite exceptional, for it differed from every other group with which it was compared.

In Figure 4 the residual logs are plotted against length of each fish, and the results show no tendency towards a change in the residual log. with increase of size.

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[1]) In most cases measured from the scale-slips or tracings used for l_1 calculation, but in certain cases by direct measurement of the scale with a micrometer. Only the striated part of the scale was measured, from apex to centre of base line.

[2]) Scales are obtained if possible from the flank of the fish between the operculum and the dorsal fin, and only of necessity from positions further back.

From Table 1 and Figure 4 it can be seen that, although the ratio fish/scale varies from fish to fish, this variability itself is a constant feature of the sprat population, and neither age, nor size, nor year of birth can alter its incidence or change its proportions.

Table 1.

Brightlingsea (Stownet) samples in the seasons 1932—33 to 1934—35.

χ^2 test of residual logarithms.
(Fish log. minus Scale log.)

Same *year-classes* (in different seasons).								Value of P
Year-class 1931[1][2]	I	group	'32/33	and	II	group	'33/34.	.48 (ca.)
	I	„	'32/33	„	III	„	'34/35.	.28 (ca.)
	II	„	'33/34	„	III	„	'34/35.	.58 (ca.)
Year-class 1930	II	„	'32/33	„	III	„	'33/34.	.39 (ca.)
Year-class 1929[3]	III	„	'32/33	„	IV	„	'33/34.	.61 (ca.)
Year-class 1932	I	„	'33/34	„	II	„	'34/35.	less than .01

Same *age-groups* (in different seasons).								Value of P
	I	group	'32/33	and	I	group	'33/34.	.02
	I	„	'32/33	„	I	„	'34/35.	.37 (ca.)
	I	„	'33/34	„	I	„	'34/35.	.015 (ca.)
	II	„	'32/33	„	II	„	'33/34.	.67 (ca.)
	II	„	'32/33	„	II	„	'34/35.	.50 (ca.)
	II	„	'33/34	„	II	„	'34/35.	.64 (ca.)
4)	III	„	'32/33	„	III	„	'33/34.	.34 (ca.)

Different age-groups (in *same season*)								Value of P
	I	group	'32/33	and	II	group	'32/33.	.28 (ca.)
	I	„	'32/33	„	III	„	'32/33.	.97 (ca.)
	II	„	'32/33	„	III	„	'32/33.	.20 (ca.)
	I	„	'33/34	„	II	„	'33/34.	less than .01
	I	„	'33/34	„	III	„	'33/34.	less than .01
	I	„	'33/34	„	IV	„	'33/34.	less than .01
	II	„	'33/34	„	III	„	'33/34.	.94 (ca.)
	II	„	'33/34	„	IV	„	'33/34.	.91 (ca.)
	III	„	'33/34	„	IV	„	'33/34.	.79 (ca.)
4)	I	„	'34/35	„	II	„	'34/35.	.50 (ca.)

Miscellaneous.								Value of P
	I	group	'32/33	and	III	group	'33/34.	.88 (ca.)

[1]) Scales were measured with micrometer; in all other cases scales were measured in cm. from scale-tracings.

[2]) Each *pair* of "arrays" contained a minimum of 5 readings; in all other cases each *member* of a pair of arrays contained a minimum of 5 readings.

[3]) IV-group only reasonably common in season 1933/34.

[4]) III-group in 1934/35 were too few for comparison (12 fish only).

Conclusions.

Since the possible explanations of L e e's phenomenon suggested in the preceding sections have been tested in the case of Brightlingsea stownet samples without positive results, and as these very samples give little or no evidence of the phenomenon itself, it seems reasonable to assume that its occurrence (shown in Figure 1) is mainly the result of net selection.

The combined samples shown in Figure 1 contain a very high proportion of fish caught by drift-nets, as may be seen from the following figures: —

Number of 2, 3, 4 and 5-zone fish for which l_1 etc. was calculated.

Season	Drift-net and Stownet (East coast)	Stownet alone (Brightlingsea)
1929/30	944	153
1930/31	240	0
1931/32	2,010	75
1932/33	3,006	250
1933/34	1,761	868
1934/35	951	309
Total	8,912	1,655

In applying L e a's formula to these samples, l_1 (also l_2 and l_3) is seen to decrease with age (Figure 1). As L is known to increase rather than decrease with age, and since the ratio L/V (fish/scale) has been shown to vary from fish to fish only, it must be concluded that v_1 (also v_2 and v_3) decreases with age in the combined samples shown in Fig. 1 and so causes the observed decrease in l_1. Where samples were obtained entirely from a relatively non-selective gear (Brightlingsea stownet) v_2 and v_3 do not decrease in this manner, and L e e's phenomenon itself is absent or much reduced[1]). On the other hand the effect of a selective gear, such as drift-nets, would be to catch only the larger young fish (with large v_1 and l_1) and a progressively greater number of comparatively small fish (with smaller v_1 and l_1) of the older age-groups.

As other explanations have been eliminated, this remains as the only likely cause of L e e's phenomenon in the combined samples, for it does not seem probable that biological selection, due to the shoaling of fish according to their size, would affect the drift-net more than the stownet fishery. Catches made by the Ministry's research vessel with a stownet on the drift-net fishing grounds have often revealed the presence of smaller sprats than those caught in the commercial drift-nets.

The sizes of v_2 and l_2 of fish from drift-nets alone (Kessingland

[1]) According to the "purity" of the sample. cf. page 223 (last para.).

samples) are given in Figure 5. The same year-class was examined in three successive years of its life, and in this case L e e's phenomenon is well marked, while v_2 likewise decreases with age.

In this respect therefore, drift-net fish are entirely different from fish caught in stownets (Figure 2), and there can be no reasonable doubt that the preponderance of fish caught in drift-nets explains the occurrence of L e e's phenomenon in the combined samples of Figure 1.

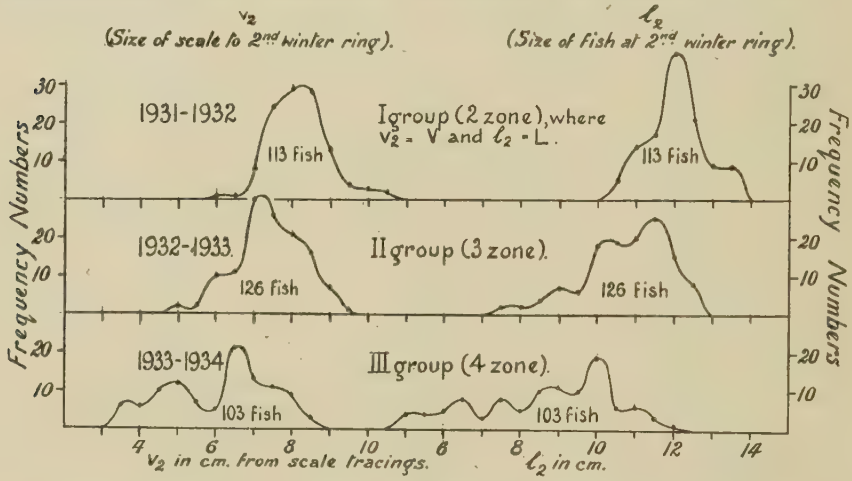

Figure 5. v_2 and l_2 in a single year-class of Kessingland (drift-net) fish.

In the course of this work it has also been found that in the case of the sprat it is safe to use L e a's method for the calculation of size at the time of formation of the winter rings, in as much as the fish and scale preserve their proportionate sizes with a constant variability, and as (in fish from relatively non-selective gear) the definitive scale-sizes of 2-zone (and 3-zone) fish do not differ markedly from the sizes of v_2 (and v_3) of the same year-class in the following season.

I wish especially to thank Mr. H. J. B u c h a n a n - W o l l a s t o n and Mr. M. G r a h a m for their help and advice on the statistical methods employed in this paper, and to acknowledge my indebtedness to them.

References.

F a g e, L. Rep. Danish Ocean. Exped. 1908/10 to Mediterranean. No. 6, Vol. II (Biology) A. 9. 1920.

G r a h a m, M. Min. Agric. and Fish. Fish. Invest. Ser. II, Vol. XI, No. 3. (1928). 1929.

H o d g s o n, W. C. Journ. Cons. Int. Expl. Mer. Vol. II, No. 3. 1927

H o d g s o n, W. C. Journ. Cons. Int. Expl. Mer. Vol. VIII, No. 3. 1933.

J e n k i n s, J. T. Wissens. Meeresunters. N. F. Bd. 6. Abt. Kiel, 1902.

L e b o u r, M. V. Journ. Marine Biol. Assoc. U. K. Vol. XII (N. S.) (p. 427) 1919/22.

M c I n t o s h, W. C. and M a s t e r m a n, A. T. "The Life-Histories of the British Marine Food-Fishes". (p. 429) London, 1897.

R o b e r t s o n, J. A. Journ. Cons. Int. Expl. Mer, Vol. VIII, No. 3. 1933.

R o b e r t s o n, J. A. Journ. Cons. Int. Expl. Mer, Vol. XI, No. 1. 1936

Further Developments in the Tagging of the Pacific Herring, *Clupea pallasii*[1]).

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A previous report in the *Journal du Conseil* (Rounsefell, and Dahlgren, 1933)[2]) described an experiment carried on at Holmes Harbor, Washington, in developing a method of tagging herring. Since the publication of that report an extensive tagging programme has been carried on in south-eastern Alaska. It is the purpose of this paper to note the results accomplished during the ensuing years, and to report a new electrical method for the recovery of the tagged individuals. Details of the method of tagging and of the method of magnetic recovery of tags were described in the former article.

These tagging experiments have had a two-fold purpose. First, by tracing the migration of the tagged individuals, to delineate the areas inhabited by each major population of herring, and to obtain thereby a measure of the degree of intermingling which occurs between stocks. The existence of these separate races had already been established (Rounsefell and Dahlgren, 1935)[3]). Second, to obtain a measure of the intensity of the fishery by considering the percentage recovery of tags.

Difficulties encountered in the use of the magnet recovery system.

The accurate tracing of migration routes by the use of magnet-recovered tags presents certain difficulties which have limited its value. First, the method of handling the raw fish often precludes an accurate statement of the area from which the tag has been returned, since the fish are conveyed from the hold of the vessel to a large tank and are

[1]) Dr. George A. Rounsefell, who had been in charge of the herring work, was transferred to another problem in July 1934. His part in the development of this tagging programme is hereby gratefully acknowledged.

[2]) Rounsefell, George A., and Edwin H. Dahlgren. 1933. Tagging experiments on the Pacific herring. Journ. du Cons. Perm. Intern. Explor. Mer., vol. VIII, no. 3, pp. 371-384, 6 figs. Copenhague.

[3]) Rounsefell, George A., and Edwin H. Dahlgren. 1935. Races of herring, *Clupea pallasii* in south eastern Alaska. Bull., U. S. Bur. Fish., vol. XLVIII, 1935, pp. 119-141, 10 figs.

stored there until sufficient fish have accumulated to begin reduction operations. Consequently, when boats from different areas return to the shore station during one "run" of the reduction unit, it is virtually impossible to state from which load, and hence from which area, the tag was taken.

Further, there is known to be a lag between the taking of the tagged individual by the fishermen and the recovery of the tag in the plant by the electromagnet. This has been demonstrated by placing fish, bearing test tags, directly in the holds of the vessels being unloaded, to find that although most of the tags were reported recovered from the magnet within two days, in occasional instances they were reported as much as three weeks later. This delay may be due to any one of several causes. One of these is "sticking" in the drier, a rotating steel drum about fifty feet long and six feet in diameter through which the damp meal is passed with an intense oil flame playing on one end so that the hot gasses surrounding the meal evaporate it to dryness. There is a tendency for meal to burn on the shell of this drum, and it is believed that tags become lodged in this material, being held there for a time before continuing through the drier. Other possible sources of delay are the conveyors which carry the dry meal to the magnet. Each of these has a "dead" end in which meal accumulates, and tags, being heavier than the dry meal, occasionally become trapped in such a place for a time before finding their way over the magnet.

In the summary of results given in the following paragraphs it is to be understood that there are discrepancies in many cases between the reported locality of recovery and the actual area from which the fish were taken, for the reasons mentioned above. In special cases, however, this error does not enter. For instance, the first fishing operations of the season for the past three years have been concentrated in the Iphigenia Bay region; the entire fleet fishes this area during the first week to ten days of the season. In 1934 eleven recoveries, and in 1935 eighty-six recoveries of tags affixed at Sitka were made at Warren Channel before the fleet had operated in any other area, giving absolute proof that the Ommaney population mingles with the Craigh population in this region. (See Figure 1). Of course, as soon as the fishing has expanded to include more than the one area, it becomes impossible to segregate the tags accurately. Consequently it is hazardous to state whether the Craig population migrates across to Cape Ommaney, although the 1935 experiment, as mentioned later, has thrown some light on this problem.

It became evident that a more satisfactory means of recovering the tags would have to be developed before the success of this tagging method could be assured. The most desirable recovery, of course, would be the isolation of the individual bearing the tag as it was being discharged from the vessel. With upward of fifty million fish taken each year from a single plant, visual examination is obviously impossible, even if a visible tag (such as the opercle tag described in a former article) were to be used. Since the belly tag is far superior to

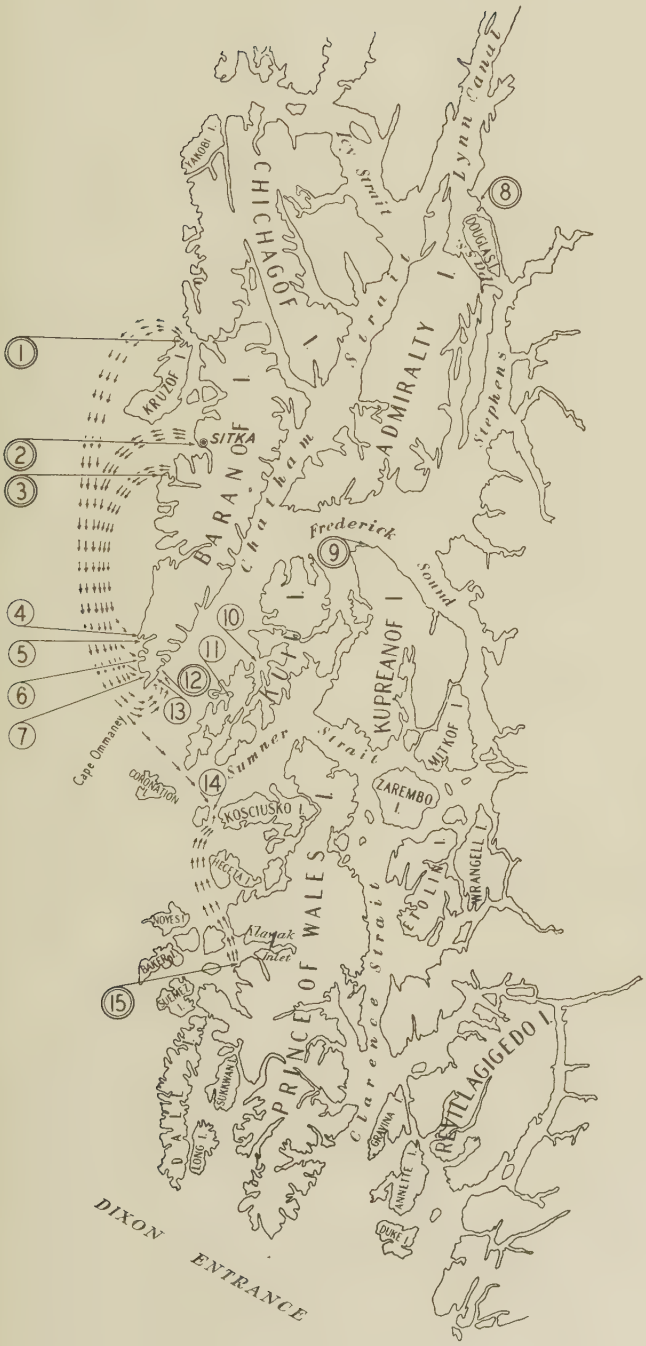

Figure 1.
Map of south-eastern Alaska, with arrows showing migration routes traced by tagging experiments. Double circles indicate tagging locations.

1. Kalinin Bay
2. Jamestown Bay
3. Redoubt Bay
4. Redfish Bay
5. Big Branch Bay
6. Puffin Bay
7. Larch Bay
8. Auke Bay
9. Cape Bendel
10. Tebenkof Bay
11. Port Malmesbury
12. Port Conclusion
13. Port Alexander
14. Warren Channel
15. Craig

the opercle type, as the experiments described below demonstrate, it became necessary to evolve some method for detecting the belly tag while still in the body cavity of the fish.

Development of electronic detector.

The problem of developing an electrical device capable of detecting the presence of a piece of metal as small as a tag was presented to Doctor C. E. Magnusson, Professor of Electrical Engineering at the University of Washington. On his recommendation, two graduate students were engaged to develop a device capable of accomplishing this. With the cooperation of Doctor Magnusson as well as other members of the faculty and with the use of University equipment, these men have designed and developed the instrument to its present form. Before describing the device and its operation, however, the results of the tagging to date will be briefly summarized.

Procedure used in tagging.

Certain changes in the technique of tagging have been made since the publication of the first report. The livebox, as used in the field, measures ten feet in width by twenty feet in length, with a three-foot depth, being partitioned off so as to leave two-thirds of the volume in one end. The fish, which are obtained either by beach or purse seine, are permitted to swim into the large end of the box by holding the cork line over the submerged edge, and "rolling" the fish into it. The smaller end of the box is used to hold the tagged individuals, so that they may be released in schools instead of singly.

In tagging, fish are dipped from the livebox into a large galvanized tub, kept filled with frequently changed water. Two men are employed at the tagging. The one man grasps a fish from the tub, and holds it firmly in his two hands while the second operator makes the incision and inserts the tag. The tagged fish is then dropped back into the box. By this method it is possible for two operators to tag three hundred to four hundred fish in an hour.

Summary of tagging experiments.

As stated in the previous report, out of a total of 3,487 herring tagged and released in 1932 (see Table 1), the recovery of ten tags from the 1,034 individuals tagged and released July 27 at Port Conclusion, gave the first real promise of success in tagging the herring. This experiment proved conclusively not only that the fish would survive the tagging, but that tag recovery by means of magnets was possible. It also gave evidence that the "inside" fish, i. e., fish taken inside Cape Ommaney, are of the same population as those taken outside the Cape. This tentatively answered the question of the homogeneity of the populations in the Cape Ommaney region.

In the same year 824 opercle tags and 996 belly tags were affixed to herring at Cape Bendel, 65 miles north of Cape Ommaney, in

Table 1.

1932 Tagging and recoveries.

Location of Tagging	Type of Tag	Number Tagged	Date	Number of tags recovered with reported locality of recapture		Total Recoveries	Percentage Recovery
				Inside Cape Ommaney	Outside Cape Ommaney		
Port Conclusion	Pure nickel	1,034	7/27/32	1	9	10	1.0
	opercle type	633	8/ 3/32	0	0	0	
	Total	1,667					
Cape Bendel	Pure nickel opercle type	824	8/17/32	0	0	0	
	Pure nickel belly type	996	8/17/32	0	0	0	
	Total	1,820					

Table 2.

1933 Tagging and recoveries.

(Including those recovered in 1934).

Location of Tagging	Type of Tag	Number Tagged	Date	Number of tags recovered with reported locality of recapture				Total Recoveries		Percentage Recovery	
				Vicinity Cape Ommaney		Unknown					
				1933	1934	1933	1934	1933	1934	1933	1934
Sitka	Pure nickel belly type	2,499	4/21-25/33	81	2	20	4[1])	101	6	4.0	0.2
	Pure nickel opercle type	1,470	4/22-23/33	7	0	0	0	7	0	0.5	0.0
Juneau	Pure nickel belly type	800	5/3-5/33	0	0	0	0	0	0		
	Pure nickel opercle type	772	5/4-5/33	0	0	0	0	0	0		

Frederick Sound. None of these tags was recovered. This negative evidence indicates that there was no intermingling betweeen this and the Cape Ommaney populations.

Encouraged by the success of the Port Conclusion experiment, tagging was continued in the spring of 1933. Tags were affixed to spawners at Jamestown Bay (near Sitka, west coast of Baranof Island) and at Auke Bay (Juneau spawning area). The recovery of 4 % of the belly tags, and ½ or 1 % of the opercle tags affixed at Jamestown Bay (see Table 2), gave the first absolute evidence of migration between the spring spawning area and the summer feeding grounds. These fish were taken at Cape Ommaney, approximately seventy miles from Sitka. This experiment proved conclusively that the belly

[1]) Three of these tags were recovered during first day's operation, indicating that they were held over in the plant from the previous year.

tag was superior to the opercle type. No recoveries were made of the previous year's tags, nor were any of those from the Juneau experiment retaken. The latter was to be expected, in the light of the racial findings made by biometrical methods (R o u n s e f e l l and D a h l g r e n, 1935).

Economic conditions had caused a decrease in the number of boats operating in 1933. The resulting lack of competition between gear led to a concentration of the entire fleet in the lower Chatham Strait (Cape Ommaney, Iphigenia Bay) region. Very few fish were taken from upper Chatham Strait, Icy Strait, or Stephens Passage, which are within range of Auke Bay. The negative evidence given by lack of recovery from the Cape Bendel experiment in 1932, or from the Juneau tagging in 1933, assumes added significance in the light of the large recovery of tags from later experiments, and it may be

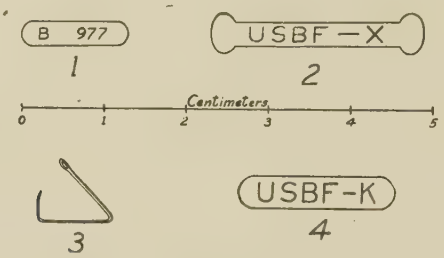

Figure 2. Types of tags used in the experiments, drawn to scale: (1) Pure nickel belly type, (2) Dumb-bell-shaped nickel-plated steel belly type, (3) Opercle type, (4) Nickel-plated steel belly type.

stated definitely that no mixture of either the Juneau or Cape Bendel populations and those of Cape Ommaney took place.

During the 1934 season, seven tags affixed in 1933 were recovered. Of these, three were taken during the first "run" of one plant, indicating that they were not taken by the fishermen during the 1934 season, but had been held over from the previous year in the machinery. The significance of this small recovery will be discussed later.

In 1934 the tagging experiments were expanded. In order to obtain a more adequate sample from which to calculate percentage recoveries, 13,167 individuals were tagged at Jamestown Bay, Sitka. In addition, an experiment was started at Klawak Inlet, Craig, on the west coast of Prince of Wales Island, in which 8,394 individuals were tagged.

A new type of tag was used for the first time in these experiments, i. e., a nickel-plated steel tag measuring 19 mm. in length, 4 mm. in width, and 1 mm. in thickness. (See Figure 2.) In the previous experiments a smaller non-corrosive pure nickel tag had been used, which measured 13 mm. by 3 mm. by 0.7 mm. Nickel, in addition to being expensive, has the disadvantage of possessing only a fraction of the magnetic properties of iron or steel. On account of the lack of oxygen, it was concluded that the ferrous metal would not corrode

Table 3.

1934 Tagging and recoveries.

(Including those recovered in 1935).

Location of Tagging	Type of Tag	Series	Number Tagged	Date	Number of tags recovered with reported locality of recapture: Warren Channel		Warren Channel or Cape Ommaney		Cape Ommaney		Tebenkof or Cape Ommaney		Tebenkof[2] Bay		Unknown		Totals Recoveries		Percentage Recovery	
					1934	1935	1934	1935	1934	1935	1934	1935	1934	1935	1934	1935	1934	1935	1934	1935
Craig	Nickel-plated steel belly type	A	2,484	3/24/34	28	7	1	3	18	6	2	0	0	0	0	10	49	26	2.0	1.0
		B	2,467	3/24/34	27	6	2	5	24	9	0	0	0	0	0	6	53	26	2.1	1.1
		C	2,488	3/26/34	23	11	2	5	20	3	1	0	1	0	0	11	47	30	1.9	1.2
		Totals	7,399		78	24	5	13	62	18	3	0	1	0	0	27	149	82	2.0	1.1
	Pure nickel belly type		995	3/25/34	4	0	0	0	2	0	0	0	0	0	0	0	6	0	0.6	0.0
Sitka	Nickel-plated steel belly type	D	2,432	4/2/34	5	2	0	5	117	18	6	0	2	0	2	26	132	51	5.4	2.1
		E[1]	2,439	4/7-9/34	3	4	0	2	78	12	4	0	2	0	2	15	89	33	3.6	1.4
		H	2,425	4/5/34	1	1	4	2	103	16	8	0	1	0	0	14	117	33	4.8	1.4
		J	2,441	4/7/34	4	2	0	4	95	15	5	0	2	0	0	32	106	53	4.3	2.2
		K	1,232	4/9/34	1	2	0	1	35	5	1	0	0	0	1	20	38	28	3.1	2.3
		Totals	10,969		14	11	4	14	428	66	24	0	7	0	5	107	482	198	4.4	1.8
	Pure nickel belly type		2,198	4/7-9/34	0	0	1	0	35	3	1	0	0	0	1	3	38	6	1.7	0.3

[1]) Not nickel-plated.

[2]) Recoveries from this area considered doubtful, since the Cape Ommaney region was being fished at the same time, and the tags reported probably were held over in the machinery.

within the body cavity of the fish. All except one series of these steel tags were nickel-plated, however, in order to reduce any possibility of corrosion, and because the process of plating insures a clean tag, and renders the distinguishing characters more legible.

In order further to reduce the cost of the tags, they were stamped with identifying characters instead of serial numbering, each lot of 2,500 bearing the same series letter or number. Since 2,500 can be applied in a day, such a system does not confuse the interpretation of the data.

Along with the 7,399 steel tags, 995 of the pure nickel tags were affixed at Craig; 10,969 steel tags and 2,198 of pure nickel were applied at Sitka. The percentage recovery of these two types of tags has given a measure of their relative efficiencies.

As expected, there was no corrosion of these steel tags, even those taken a year and a half later appearing as bright as when first made. Those of the series "E", which were not nickel-plated, discoloured, showing a greyish-black appearance which, however, was not to be confused with ordinary rust.

The recovery of 0.6 % of the pure nickel tags affixed at Craig, compared to 2.0 % of the nickel-plated iron tags from this same experiment, and the recovery of 1.7 % of the pure nickel tags from Sitka, compared to 4.4 % of the nickel-plated iron tags from this experiment, (see Table 3) definitely proved the latter to be much more efficient. The reason for the greater recovery of the iron tags probably lies in the greater permeability of steel, which has approximately ten times the magnetic properties possessed by nickel, and in the increased size, which not only makes their attraction to the magnet more positive, but makes for greater visibility to the operator who removes them from the magnet.

The recovery, during the 1935 season, of 82 (1.1 %) of the steel tags applied at Craig in 1934, and, during 1935, of 198 (1.8 %) of the steel tags affixed at Sitka in 1934, was not as high a percentage recovery as might be expected in view of the much higher percentage recovery of the 1935 tags. The difference in the percentage recovery between two seasons, taking into consideration the percentage taken of the second year's tags, gives an estimate of the natural mortality which occurs during that time. Until more reliable recovery data are available, however, no attempt will be made to evaluate the natural mortality.

In 1935, tagging was again carried on at Craig and at Sitka. As in the 1934 experiment, a large number of individuals were tagged, in order to obtain more reliable data on mortality. In this experiment, 13,008 herring were tagged at Klawak Inlet, off Craig, and 20,157 at Jamestown Bay, Sitka. In addition, 5,141 individuals were tagged at Kalinin Bay, Salisbury Sound, about 25 miles north, and 2,613 at Redoubt Bay, 15 miles south of Sitka.

Again a new type of tag was used, a steel tag with a "dumb-bell" shape, measuring 26 mm. in legth, 1 mm. in thickness, having a shank

1935 Tagging and recoveries.

Location of Tagging	Type of Tag	Series	Number Tagged	Date	Number of tags recovered with reported locality of capture: Warren Channel	Warren Channel or Cape Ommaney	Cape Ommaney	Tenakee[3] or Cape Ommaney	Unknown	Total Recoveries	Percentage Recovery
Craig	Nickel-plated steel belly type	1	2,505	3/19/35	17	10	4	0	17	48	1.9
		2	2,508	3/20/35	18	8	6	0	18	50	2.0
		3	2,500	3/22/35	18	20	10	0	31	79	3.2
		4	2,449	3/23/35	7	13	5	0	31	56	2.3
		Totals	9,962		60	51	25	0	97	233	2.3
	Dumb-bell-shaped nickel-plated steel belly type	1	1,027	3/20/35	2	2	2	0	2	8	0.8
		2	1,019	3/22/35	9	4	3	0	8	24	2.4
		3	1,000	3/23/35	3	4	1	0	10	18	1.8
		Totals	3,046		14	10	6	0	20	50	1.6
Sitka	Nickel-plated steel belly type	5	2,471	3/28/35	5	12	98	3	96	214	8.7
		6	2,473	3/29/35	12	10	99	1	80	202	8.2
		7	2,484	3/30/35	3	4	44	2	34	87	3.5
		8	2,550	3/30/35	5	11	63	4	78	161	6.3
		0	2,552	3/31/35	12	17	102	7	90	228	8.9
		Z	2,594	4/1/35	11	14	96	1	101	223	8.6
		S[1]	2,525	4/3/35	4	8	66	3	74	155	6.1
		T[2]	2,616	4/4/35	2	3	64	4	63	136	5.2
		U[3]	2,613	4/5/35	10	10	105	4	103	232	8.9
		Totals	22,878		64	89	737	29	719	1,638	7.2
	Dumb-bell-shaped nickel-plated steel belly type	4	1,004	3/29/35	9	7	35	1	38	90	9.0
		5	1,010	4/1/35	4	6	30	3	26	69	6.8
		6	996	4/1/35	4	3	37	0	31	75	7.5
		7	1,008	4/1/35	3	4	45	1	27	80	7.9
		0	1,015	4/2/35	2	4	43	2	37	88	8.7
		Totals	5,033		22	24	190	7	159	402	8.0

[1]) Tagged at Kalinin Bay.
[2]) Tagged at Redoubt Bay.
[3]) Tenakee recoveries considered doubtful, since the Cape Ommaney region was fished at the same time, and the tags probably were held over in the machinery.

20 mm. long by 2.8 mm. wide, and with bulbous ends 5.4 mm. in width. The new type, which is 7 mm. longer than the others, was used so as to have an increased length of metal, since this increase gives the newly developed electronic device a much greater probability of detection. The shank of this tag was reduced in size so as not to increase the weight greatly, and the bulbous ends were used to prevent the tag from working out of the fish as easily as would be the case if they were as narrow as the shank of the tag.

The recovery of 2.3 % of the plain-type tags, compared to 1.6 % of the dumb-bell-shaped tags from the Craig experiment, and 7.2 % of the plain type compared to 8.0 % of the dumb-bell-shaped tags from the Sitka tagging, (see Table 4) shows no difference in the efficiency of the two types. Apparently the increase in length of the tag caused no additional mortality due to tagging.

The recovery of the tags affixed at Kalinin Bay and at Redoubt Bay showed that these populations intermingled with the Jamestown Bay population on the feeding grounds. The spawning area on the west coast of Baranof Island extends from above the upper end of Kruzof Island on the north to below Redfish Bay on the south — a distance of approximately 60 miles — and spawning occurs on suitable grounds throughout this area. The spawning varies from season to season so that areas which in one year are heavily spawned show very light spawning the following year. This fact, coupled with tagging returns from the spawning areas mentioned, leads to the theory that the entire coastline is inhabited by one stock of herring, which migrates to Cape Ommaney (with occasional strays going across to Iphigenia Bay) during the feeding season, to return again to this area for spawning the following spring. A more extensive tagging to include the areas south of Redoubt Bay as far as Redfish Bay will check this theory.

Estimates of mortality.

There has always been a question as to how large a percentage of the population is taken by the fishery. The popular belief has been that only an immeasurable part is caught, and that the decline in abundance observed in certain intensively fished districts has been due entirely to the emigration of the herring from that area.

Assuming that the tagged fish are distributed with the remainder of the population in a random manner (which appears to be the case, from the fact that tags are returned from the various separate markings throughout a greater part of the season), then the percentage recovery of tags gives a measure of the percentage of the total population taken. The figures herein given are admittedly in error, and represent the absolute minima of imposed mortality. There are three known sources of error which, at present, cannot be evaluated. First, there is probably a mortality caused by the tagging; second, there may be a loss of the tags by their working out of the herring in life; and third, there is a failure to obtain all the tags recovered by the fishermen, due to

the inefficiency of the magnets, the loss of tags to souvenir hunters, and the failure of some of the plant operators to return recovered tags. Each of these factors, of course, reduces the percentage recovery.

Without considering these sources of error, however, it is clearly evident that the fishery takes an appreciable toll from the populations in the more intensively fished areas. That this is the case in the Cape Ommaney fishery is evidenced by the recovery of 4 % of the Sitka tags in 1933, 4.4 % in 1934, and 7.2 % in 1935. The second main population from which the fishery is drawing is that which spawns at Craig. For this fishery, a 2.0 % return in 1934, and 2.3 % in 1935 indicates that it is not as intensively fished as is the Sitka population. This, too, appears reasonable from the fact that the Warren Channel area is fished intensively only during the first two or three weeks of the season, after which time these grounds are abandoned for more favourable areas. Consequently, it is only during a fifth of the fishing season that this population is subject to the inroads of the fleet, whereas the Cape Ommaney district is fished during practically all the rest of the four month open period.

Certain of the plants, on account of more efficient magnet installations and greater willingness to cooperate in the collection of tags, are known to give a more reliable return than the others. Basing the 1934 recoveries on four of the seven plants operated, it is found that these plants returned 341 of the Sitka tags, and 103 of the Craig series. Since these four plants took 55 % of the total season's catch, it is estimated that, had the other plants returned as large a proportion of tags as did those mentioned, 5.7 % of the Sitka tags and 2.5 % of the Craig tags would have been returned. On this same basis five out of the eight plants operating in 1935 returned 1,312 plain and 323 dumb-bell-shaped tags from the Sitka experiment, and 175 plain and 38 of the dumb-bell type from the Craig experiment. Since these plants took 64 % of the total catch for the season, then 9.0 % of the plain and 10 % of the dumb-bell type from the Sitka tagging; and 2.7 % of the plain and 1.9 % of the dumb-bell type from the Craig experiment should have been returned. While these figures are, at best, only estimates of the percentage mortality imposed on the population by the fishery, they are doubtless more indicative of the actual percentage taken than are those given in the tables.

The perfection of the electronic device, discussed in the following paragraphs, to the point where it will recover all the tags from the fish searched, will permit an accurate estimate of the percentage taken by the fishermen, together with a measure of the validity of that estimate, based on the variation between the number of tags per load throughout the season. If an adequate sample of the spawning population is tagged, and an estimate of the mortality caused by tagging and the loss of tags by the fish can be made, then statistically reliable figures will be available of the mortality imposed by the fishery. An estimate, too, of the total numbers of fish in a given population will also be available, based on the return of tags per barrel.

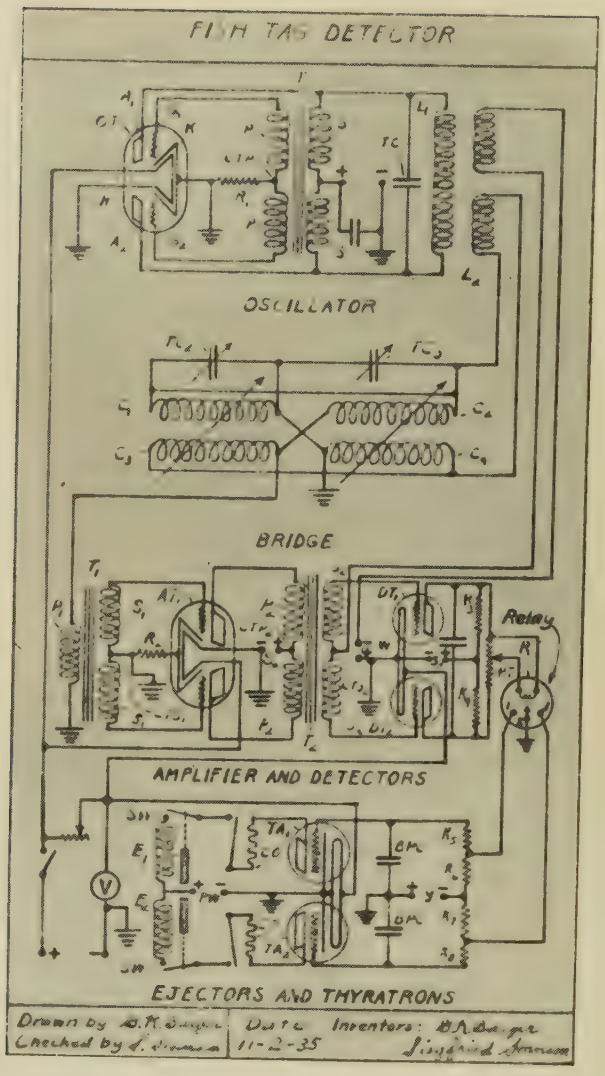

Figure 3. Wiring diagram of the electronic tag-detector circuit.

Description of the electronic tag-detector.

The operation of this device is dependent on an elaboration of a tuned bridge circuit. (See Figure 3.) Two sets of paired coils are so connected and arranged that their respective electro-magnetic fields are in balanced opposition to each other. Consequently, current passing through the one pair is neutralized by the current passing through the other. As a result, in the normal, balanced condition the current

potential passing from these coils into the amplifier and detectors is neutralized and effectively cancelled out, so that the normal input approaches zero.

It is characteristic of coils, however, that changing them in any of several ways changes their electro-magnetic field. Thus, if a core of metal is placed through the centre of a coil, the change in the inductance of that coil can be measured by an ordinary instrument.

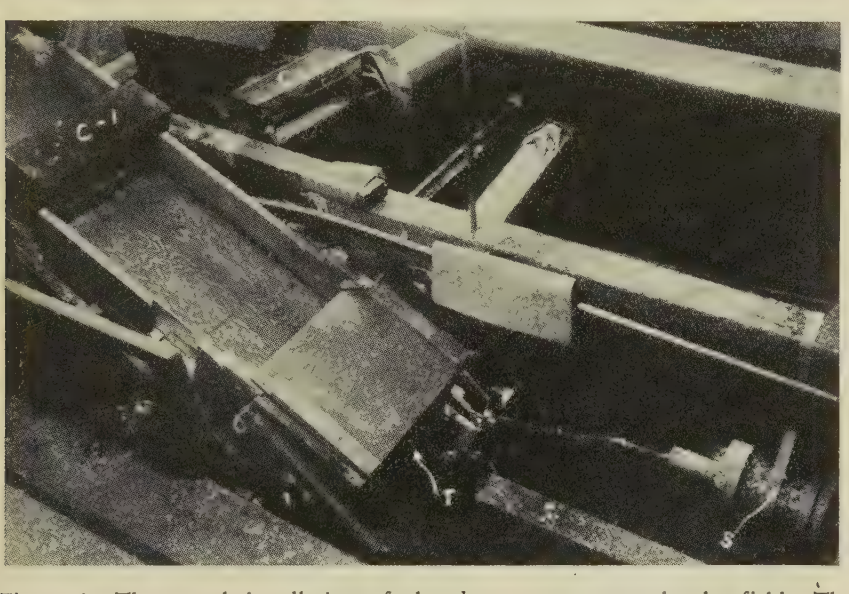

Figure 4. The actual installation of the detector apparatus in the field. The presence of a metal tag passing through the core of the encased coil-pair C-1 transmits an impulse through wires carried in the pipe to the unit, which is mounted about fifteen feet distant. The power surge developed in the set operates the solenoid coil S, releasing the trap door T, which is closed by the springs shown, thus boxing off a part of the chute. The flow of fish is then cut off. The fish held in the box are passed through the coil a few at a time until the tag again activates the unit, which indicates the presence of the metal, enabling the operator to select the tagged individual. The trap is then reset, the unit is again ready for operation, and the flow of fish continues. The balancing coil-pair C-2 is also shown.

This principle, made much more sensitive by the use of paired coils in tuned opposition, and by amplifying the impulse before detecting it, has made it possible to detect the metal tag, weighing only 0.45 grammes, passing through a coil with a 5″ × 20″ core area.

To explain in another way, the presence of a metal tag in the field of one of the sets of paired coils destroys the balance which has been set up. This "unbalance" is amplified and detected by the unit, which converts this impulse, through a sensitive relay and the use of gaseous control tubes, to control the necessary power circuit. This control circuit is used to operate a mechanical device for isolating

the tagged individual. In the present set-up, this is so arranged as to hold, in the chute on which the fish are carried, the individual bearing the tag, along with such others as may be in the field at the time of detection. It is then necessary only to separate the

Figure 5. Herring passing through the coil, being mechanically searched for tags. The assembly is mounted so that the fish drop from the chute directly into the storage tank. Approximately 5,000 fish per minute pass through the coil.

individual bearing the tag from the others ejected, by passing the lot of fish, a few at a time, through the coils again, in which case the same unbalance occurs, the same series of impulses follow, and the individual bearing the tag is isolated.

The design of an instrument capable of doing this in the laboratory is comparatively simple. The application to field conditions, however, coupled with the fact that the centre of the coils must be of a size

to permit the passing of 5,000 fish a minute, has been much more difficult. The detector must be sensitive enough to register a change of one part in many thousands — a change so small that extreme sensitivity must be maintained in all parts of the circuit.

More detailed information on the design of the detector, and of the mechanics of installation, are available through the Bureau of Fisheries Laboratory at 2725 Montlake Boulevard, Seattle, Washington.

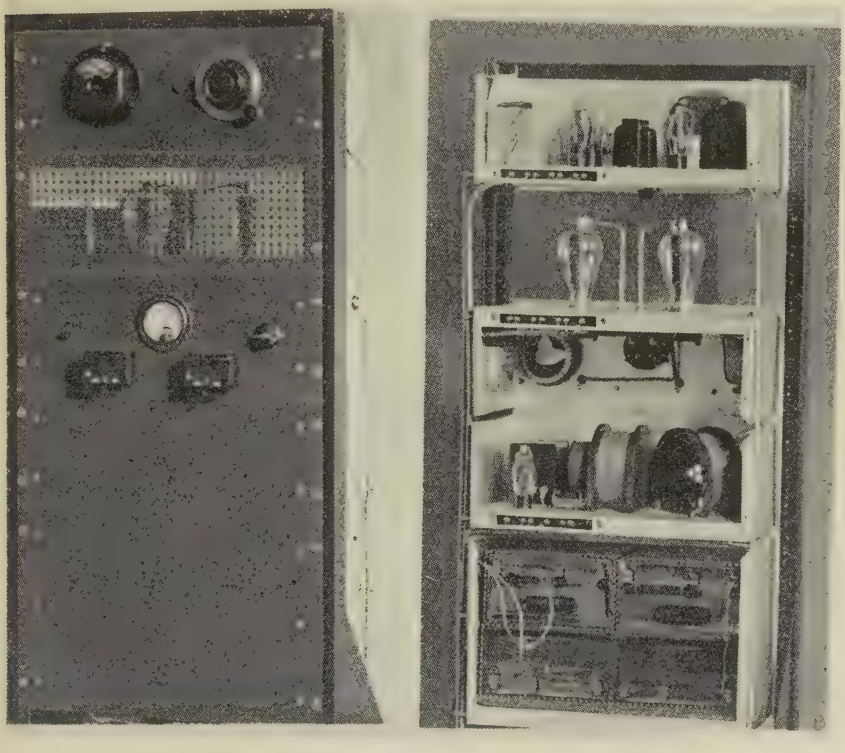

Figure 6. Front and back views of electronic tag-detector assembly. This unit, situated at some distance from the coils through which the fish pass, converts the "unbalance" created by the presence of the tag in the coil, into a power impulse for mechanical ejection of the individual bearing the tag.

Operation of the unit.

The first unit was installed in the field in the 1935 season. (See Figures 4 and 5.) During the short time the unit was in operation, 66 tagged individuals were recovered. Mechanical difficulties of installation and operation, to be expected in the development of such a device, precluded the recovery of a larger number of tagged individuals. In addition to proving the feasibility of the device, however, this first season's operation has given some valuable information.

Table 5.

1935 Detector recoveries.

Location of Tagging	Type of Tag	Years of Tagging	Number of tags recovered with locality of recapture						Total Recoveries
			Outside Cape Ommaney			Inside Cape Ommaney			
			Big Branch Bay	Puffin Bay	Larch Bay	Off Port Alexander	Port Conclusion	Port Malmesbury	
Jamestown Bay	Nickel-plated steel belly type	1934			1	2			3
		1935	5	1	7	15		1[1])	29
	Dumb-bell-shaped nickel-plated steel belly type	1935		2	2	7	1		12
Kalinin Bay	Nickel-plated steel belly type	1935		1		12			13
Redoubt Bay		1935	3			5	1		9
	Totals		8	4	10	41	2	1	66

[1]) Locality doubtful because small part of load taken at Cape Ommaney, balance at Port Malmesbury.

Figure 7. Gonads of the herring, with tags imbedded in the tissue. The tag is surrounded with sex products which are not re-absorbed, although the rest of the organ appears normal.

Summary of detector recoveries.

The recoveries from the detector are listed in Table 5. In this table, with the one exception noted, the localities of recoveries are known to be reliable. It is significant that, out of these recoveries, no Craig tag was retaken. Therefore, while it is known that the

Sitka spawners do migrate to Warren Passage, and that they mingle with the Craig population there, it appears that a counter migration (Craig fish to Cape Ommaney) did not take place.

The recovery of Sitka tags from Big Branch Bay, Puffin Bay, and inside Cape Ommaney as far as Port Conclusion, definitely proved that those taken at any place in the Cape Ommaney region are from this population. The recovery of Kalinin Bay tags, and of Redoubt Bay tags, along with those of Jamestown Bay, proved these to be of one population. It is therefore possible to state definitely that the Sitka population, which migrates to Cape Ommaney during the feeding season, is composed of individuals which spawn as far north as Kalinin Bay, and at least as far south as Redoubt Bay.

A clue to the cause for the failure to recover a larger percentage of tags during the second year is furnished by the fact that in 59 of those recovered, the tag had penetrated the gonad. (See Figure 7.) At the time the tags are applied, the fish are so ripe and distended with spawn that it is virtually impossible, apparently, to insert a tag without puncturing the organs. That the fish spawn after the tagging is attested to by the normal appearance of the ova and milt in the organ, except for an accumulation of unspent products adhering to the tag itself. This accumulation, which is not re-absorbed, becomes extremely hard, and adheres tightly to the tag. It is quite possible that this interferes with the spawning during the next season, and as a result the individual fails to survive, although, of course, this is only a matter of conjecture. Experimental tagging, as well as continued field experiments, will be necessary to obtain definite information on this matter.

Summary.

Accurate tracing of migration routes, and estimates of the intensity of the fishery by the interpretation of the data provided through the recovery of tagged individuals, while partially successful with the use of magnet recoveries, must, at least in the case of the Alaska herring, depend on the use of the newly developed electronic device for its ultimate success.

It has been definitely established that the population which spawns in the vicinity of Sitka, within the range bounded by Kalinin Bay on the north and Redoubt Bay on the south, is of one stock, which intermingles on the summer feeding grounds. From observations of the spawning habits of the herring, it is concluded that the entire spawning population of the west coast of Baranof Island is included in this stock.

It has also been established that this Baranof spawning population migrates during the summer feeding season to the Cape Ommaney region, with occasional migrants appearing at Warren Channel, in the Iphigenia Bay region, mingling with the Craig population there.

Negative evidence indicates that no counter migration of this Craig population to Cape Ommaney takes place.

The lack of recoveries from the Auke Bay and the Cape Bendel experiments prove these stocks to be separate from those of Cape Ommaney, confirming the racial data which has been published.

The belly-type tags have proved superior to the opercle type. Of these, the nickel-plated steel have proved more efficient than the pure nickel ones. Increasing the size of the steel tags caused no additional tagging mortality.

An estimate of the mortality imposed by the fishery, based on the percentage recovery of tags, admittedly in error and representing only the minimum mortality, shows that intensive fishing takes a much greater toll from the stocks than has been generally supposed by the industry. Basing the percentage recovery on the number of tags retaken by those plants known to give the most accurate returns shows that in 1934 5.7 %, and in 1935 at least 9.0 %, of the population which spawns in the vicinity of Sitka is taken by the commercial fishery. For that population which spawns in the vicinity of Craig, a 2.5 % recovery in 1934, and a 2.7 % recovery of the plain type tags in 1935, indicates that this population does not contribute as large a percentage as does that taken in the vicinity of Cape Ommaney.

Perfection of the electronic device will permit of an accurate evaluation of the percentage mortality imposed by the fishery, together with a measure of the validity of that estimate, based on the variation in number of tags recovered per unit of fish delivered throughout the season.

The application of electronic detection to the recovery of fish, bearing metal tags, is succesful. This will make possible tracing migrations and establishing mortality statistics in other fisheries, by the use of this method, since the recovery need no longer depend on the utilization of the fish for reduction.

The Run of Elvers in the River Bann, Northern Ireland.

By

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ONE of the largest and perhaps the generally best-known elver migration occurs in the Severn. Here for a very long time the migration has been recognized and commercial advantage has been taken of the presence of the little fish. The local population have caught them for their own consumption and for sale in the neighbouring towns and villages.

In the river Bann in Northern Ireland, where the most important European eel fishery dependent upon the natural production of the water exists, the presence of the elver run has also been noted. Here, however, the elvers are not captured as in the Severn but their upward progress is guarded and their passage over obstructions (e. g. weirs) assisted by means of passes specially provided for the purpose.

General observations of the run of elvers have been made on the Bann over a very long period of years, and for the past four years a much more exact record of the migration has been obtained.

Since 1860 the lower Bann has been a partially canalized river with a level controlled and regulated, so far as is possible, by weirs for the purpose of facilitating navigation. In the year 1930 the Government of Northern Ireland decided to make extensive alterations in the river channel in the interests of land drainage and it became evident that, in the course of these operations, the run of elvers would necessarily be interfered with.

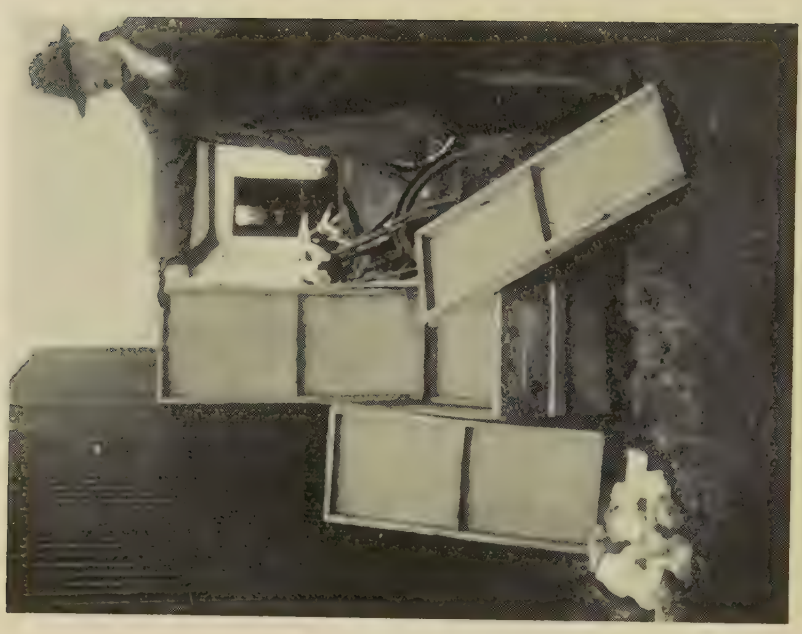
In 1933 arrangements for the natural migration of the elvers past certain of the works in the middle reaches of the river became exceedingly difficult. It was, therefore, decided to trap the elvers at the lowest obstruction in the river channel and transport them alive by road to a part of the river situated above all the works offering obstacle to their progress.

1. Elver slip with straw ropes in position.

2.a. Looking up elver slip with flap closed.
From river side.
No straw rope on chute.

2.b. Elver trap open ready to take out fish

2.c. Top of elver slip showing trap



3. Trays from box for carrying elvers.

4. Net used for catching elvers in river Severn.
Photo: L. Hugh Milne.

At the top of the tide way, at a place called The Cutts about ¾ mile above Coleraine, a weir about 6 ft. high existed for the control of water level. In the middle of this were situated salmon traps (called cribs) and at each bank an elver pass up which the little fish were able to go.

In the course of the works the weir between the cribs and the left bank of the river was replaced by a line of sluices with a short portion of new concrete weir between the end sluice and the bank. In this new weir a fresh elver pass was made thirty-one feet long, three feet six inches wide and having a uniform gradient of one in four. The old elver pass at the left bank was of similar form. The details are shown on the plan in Fig. 1 and Plate 1.

When elvers are expected ropes, loosely woven of straw, are affixed to the top of, and laid in, the passes and are so arranged that a gentle stream of water flows down them. The elvers always travel close to the side of the river, ascend along the top and underneath the rope, and so pass on to the water above.

At first sight it might appear from an inspection of the plan that the foot of the new pass is situated too far downstream and that the elvers, having gone beyond the pass, might not return to it. This might have been the case had a small amount of water flowed steadily over the top of the sluice. But this is not so. The top of the sluice is normally dry and if the sluice be open from below then the velocity and quantity of water is such as to sweep the elvers downstream. In the latter event the projecting toe of the pass forms an eddy into which the elvers can easily swim and thence gain the passage upstream. Some elvers do go past the pass, when the sluices are closed and dry, as the tide rises but these return again to within reach of the pass as the tide ebbs.

At the time of a big run the whole pass may be a moving, wriggling black mass of elvers which are preyed on by every imaginable creature; adult eels and trout, various gulls and other birds, even rats, take their toll.

The general idea of the trapping arrangement was that after the elvers ascended the pass they should enter not the open river but a simple box trap. However, various difficulties were met with and finally Major M. Mallet, Resident Engineer for the Government of Northern Ireland, devised the plan shown in Figs. 1 and 2 and in Plate 2. At first the chute carrying the water discharged on to the top of the straw rope but it was found that so exact was the affinity of the elvers for running water, and not merely for a damp lead, that they would not follow down the straw into the trap itself until a limited amount of water was discharged through the slit in the chute, so as to fall exactly on top of the rope and thence into the tank.

Once this arrangement was arrived at the success achieved was such that the whole of the run was caught. The velocity of the water through the fish traps (cribs) in the centre of the weir was too great to allow of any elvers ascending by that route and they were

unable to ascend the weir wall or sluices at any point, other than through the passes.

The elvers which enter the trap were periodically removed, weighed, placed in boxes and conveyed by motor lorry to a point on the river, or to Lough Neagh at the head of the lower Bann, where, after consultation with the Toome Eel Fishery Ltd., they are again placed in the water. In this way a very accurate record was obtained of the numbers and the movements of the elvers as they came straight from the sea and ascended the six miles of tidal waters from the mouth of the Bann to the Cutts.

The numbers of elvers were ascertained by counting a sample pound weight, which proved to be 1400 elvers, and then estimating the day to day totals from the accurate weight of the catch and by using the experimental count as the basis of calculation.

The little fish were transported in boxes, three feet six inches by one foot eight inches by two feet high (Fig. 1 and Plate 3) in which are trays having linen bottoms on which the elvers are thinly spread. For these short journeys each tray can take about 10,000 elvers. If put on too thickly they are apt to be choked in their own slime. If the period of detention in fresh air is too long they have to be gradually re-introduced to water by first sprinkling them lightly with a watering can and then gradually increasing the quantity till they are again totally immersed. But for the very few hours detention involved in catching, weighing, and transporting in the Bann operations such precautions were found to be unnecessary.

The first fact which has emerged from the observations is that each run of elvers is coincident with a spring tide period, and that during neap tides no elvers normally arrive in the river. Usually the blank period consists of four or five days but occasionally may be a day shorter. During the three years of observation a real run during the neap tides only occurred twice (May 1935)[1]).

A run does not build up steadily from the time the tides start to increase in height until the biggest tide is reached, but the numbers fluctuate in a rather irregular manner, possibly due to the influence of weather as well as to the state of the sea at the bar at the river mouth. The Bann enters the sea in a straight channel between training walls so that the state of the sea might be expected to have a considerably greater influence than in, for instance, a wide estuary such as Lough Foyle (next to the Bann) or as the Severn.

The elvers arrive by day and by night indifferently although in the Severn estuary they seem to travel more by night, or during the hours of darkness are more subject to capture by the small hand nets, resembling oblong landing nets, (Plate 4) which are used for the purpose.

The only definite deterrents which apparently exist to a run once it has commenced are a cold northerly wind or, to a still greater

[1]) And again in 1936.

degree, a frosty night. Both these factors, or the temperature factor which they imply, are quite decisive in putting the elvers down and even causing those which may be on the ropes in the passes to take cover either beneath or actually within the straw bands. The largest runs occur with south, south-west and west wind, with warm showers or moist weather. No matter how great the run might be, if the wind moves to the north, they immediately disappear and the run stops. This result may possibly be accentuated by the situation of the Cutts which face the north, so that the north wind blows upstream, and the elver slips are very much exposed to it.

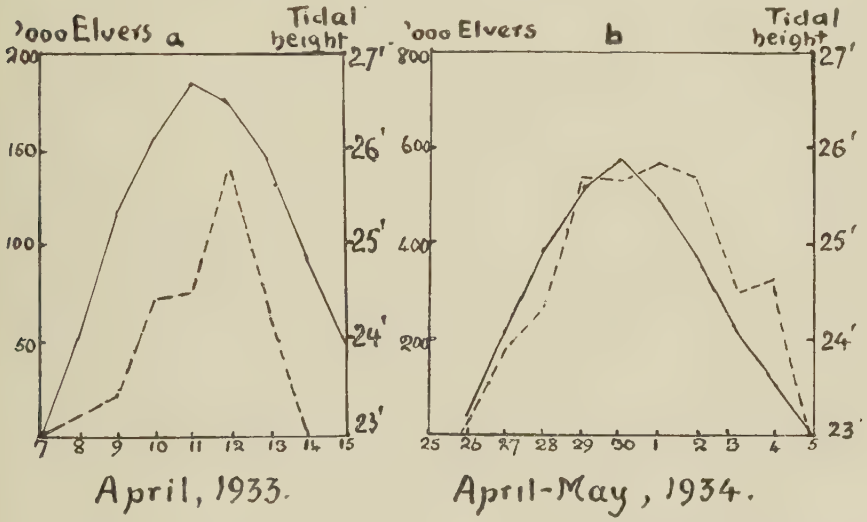


Fig. 3.

As an illustration of the very close connexion between the tidal heights and the elver runs I give two pairs of curves (Fig. 3) showing the relationship between the two. The exceptional conditions which prevailed in 1935 when the elvers ran during a neap tide and not to the usual extent in the following spring tide I also illustrate (Fig. 4).

In 1913 Dr. Bowman of this Board published a paper (1) recording the position and date of captures of elvers in the open sea round the coasts of Scotland. He found the *leptocephalus* stage off the west and north-west of Lewis, and north of the Shetlands, in July and August, and the glass elver stage off the east coast from November to March. He had a particularly good series in and off the Firth of Forth in December to March and in the upper firth in April. Norwegian observers had at that time found the same stage in the North Sea in March and April as had also Danish scientists close to their own coast.

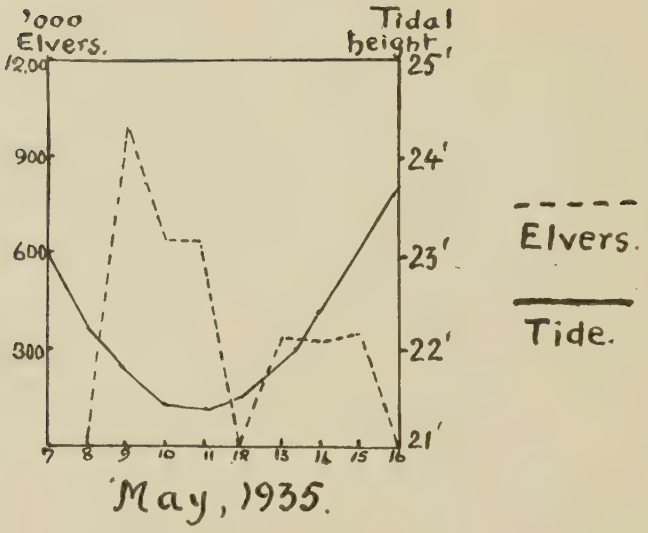


Fig. 4.

Later (1922) Professor Schmidt (2) announced his classic researches and showed that the *leptocephali* arrive off the coastal banks of Europe in their third summer and during the succeeding autumn and winter undergo the retrograde metamorphosis which converts them, at a shorter length, into glass elvers. I (3) have found elvers in the glass elver stage in the stomachs of trout caught in the estuary of the Howmore river (South Uist, Outer Hebrides) in February 1927.

No elvers have been found in the Bann so early in the year. The first arrivals at the Cutts are in April but in the first spring tide of that month the numbers are meagre (1933 and 1935) or none may come at all (1934).

Large numbers of elvers may come in the second spring tide in April (1933 and 1935) although the catch in that month in 1934 was much smaller than in either of the other years. May is usually the most important month although June, when the majority of the catch are taken in the first half of the month, follows it closely. Only a few elvers, quite unimportant stragglers, arrive at the beginning of July and the run then ceases. The proportion of the catch taken in each month in the three years in question is as follows: —

Percentage of Catch.

	1933	1934	1935
April	35.	12.5	38.
May	33.	48.	45.
June	29.	39.	15.
July	3.	.5	2.
Total.....	100.	100.	100.

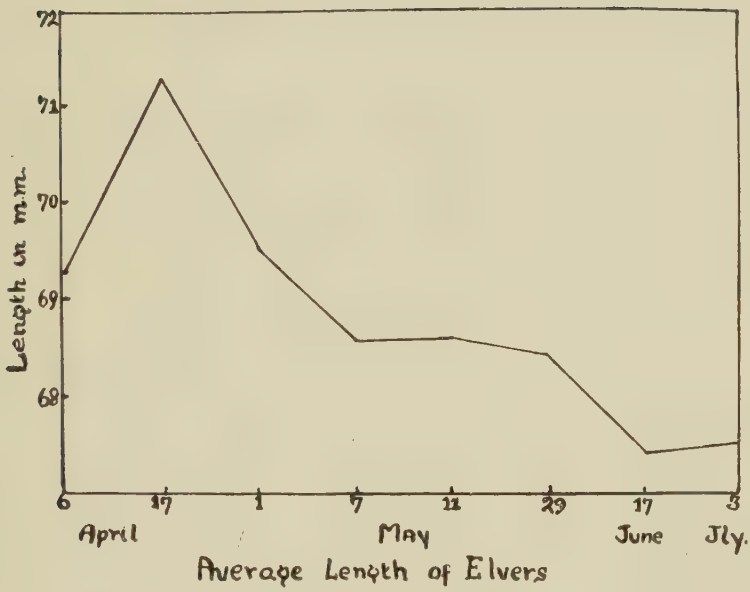


Fig. 5.

The actual numbers dealt with may be of interest. They are given in the following table in round figures.

Numbers of Elvers.

	1933	1934	1935
April	3,500,000	1,900,000	7,700,000
May	3,300,000	7,500,000	9,100,000
June	2,900,000	6,100,000	3,000,000
July	300,000	100,000	500,000
Total ..	10,000,000	15,600,000	20,300,000

The largest catch in the 24 hours consisted of 1,440,000 elvers on 10th May 1934. The elvers in the earlier part of the run are not strongly pigmented but the amount of colouring matter quickly increases and those in the later part of the migration are fully developed in this respect.

Professor Schmidt also found (2) that during the metamorphosis of the larvae they not only lose a substantial part (75 %) of their weight but also a material portion of their length. Thus while the leptocephalid larvae of June 1905 averaged 75 mm. in length the glass elvers of May 1906 were only about 66 mm.

The 49 glass elvers recorded by Dr. Bowman *(loc. cit.)* averaged 68.4 mm.

During 1935 I caused samples (consisting of 100 elvers each) to be taken and preserved at intervals throughout the run. Eight such samples were taken and these 800 elvers on their way up the Bann average 68.8 mm. in length.

Of the individual samples the average lengths have also been calculated. These do not show (Fig. 5) a progressive increase in length as might be expected but a decrease of almost four millimetres during the season. The later fish also are obviously thinner and these facts would suggest that the process of deterioration indicated at the metamorphic stage is, at least to some extent, progressive until the little fish reach fresh water.

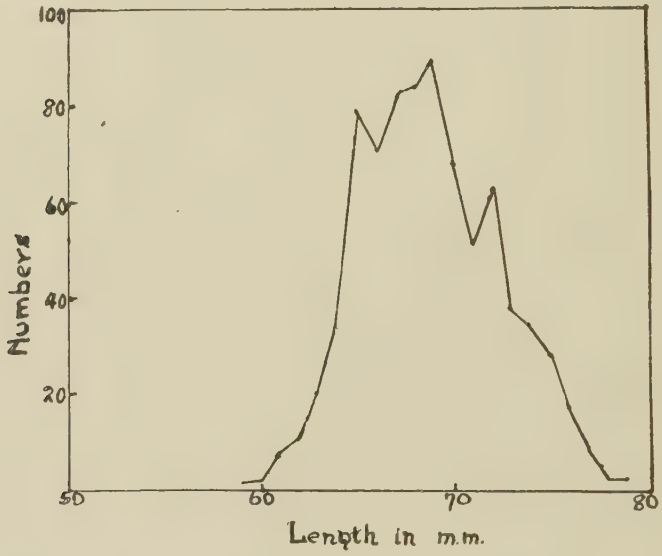
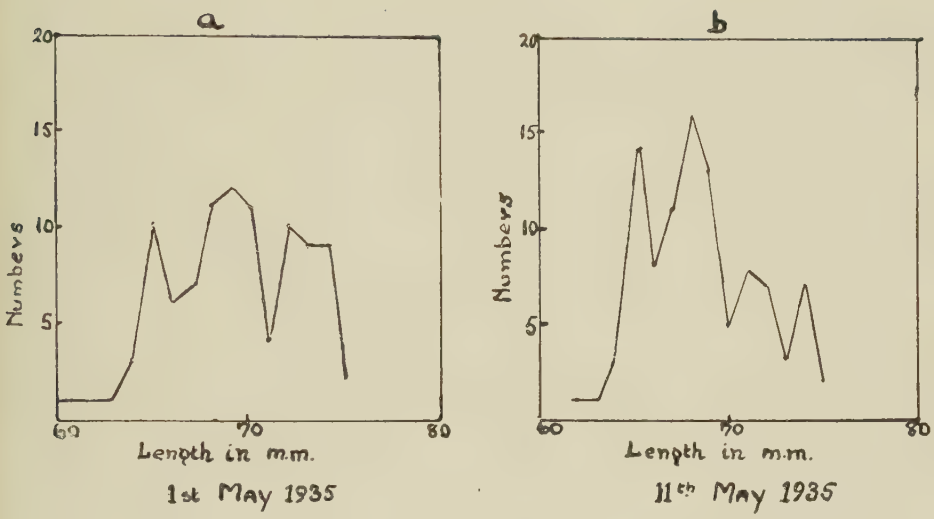


Fig. 6

Figure 5 shows that after an increase from the first sample (taken on the day when a very small number of elvers first appeared at the Cutts and which may not have been representative of the general body) there is a steady decline in the average length until the end of the season. Throughout the whole time the averages are greater than the size given by Professor S c h m i d t, but the general average is very close to that of Dr. B o w m a n.

A curve of the length frequencies (Fig. 6) does not demonstrate a quite homogeneous sample although it must be complicated to some extent by the progressive decrease in size. Curves of the individual samples e. g. 1st May and 11th May (Fig. 7, a and b) similarly are somewhat erratic and suggest a bi-cuspid distribution.

Bearing in mind the known difference in the lengths of the sexes in the adult stage it seemed possible that this same variation might be observable even at this very early period in the life of the fish.



(a) Fig. 7. (b)

Dr. John Berry kindly undertook to look into the possibility of determining the sexes of the elvers and with the permission of Professor W. Rae Sheriffs the work was done in the latter's laboratory at University College, Southampton. Unfortunately it was found to be impracticable to determine the sex at this early period of life.

The design of the elver trap and the supervision of the work of trapping were undertaken by Major Maurice Mallet, Resident Engineer for the Government of Northern Ireland and the actual work of handling and transporting the elvers was successfully carried out by Sergeant Henderson, late Royal Ulster Constabulary; throughout they worked in as close collaboration as possible with the lessees of the eel fishery, the Toome Eel Fisheries Ltd.

Bibliography.

1. Bowman, Alexander, D. Sc., "The Distribution of the Larvae of the Eel in Scottish Waters" — "Fisheries, Scotland, Sci. Invest., 1912, 2".
2. Schmidt, Johs., D. Sc., "The Breeding Places of the Eel" — Philosophical Transactions of the Royal Society of London, Series B., Vol. 211, 1922.
3. Menzies, W. J. M., "The Common Eel and its Capture" — "Fisheries Scotland, Salmon Fish., 1932, VI".

Reviews.

A. Defant. "Der äquatoriale Gegenstrom". Sitz.-ber. Preuss. Akad. d. Wiss. Phys.-Math. Kl. XXVIII. Berlin, 1935.

D e f a n t emphasizes the fact that the characteristic feature of the equatorial counter-current is not, strictly speaking, an equatorial current, since it is met with to the north or (in the Indian Ocean) to the south of the equator. The lack of symmetry must be due to the fact that the circulation of the upper layers in the oceans (the tropospheric circulation) is unsymmetrical with respect to the equator, for which reason the counter-current develops as a dynamically necessary link in the whole system of surface currents. This opinion was first advanced by the present reviewer, and was based on the observations of the "Carnegie" from the Pacific Ocean. D e f a n t shows that the dynamics of the Atlantic counter-current are quite similar, and mainly, by means of the "Meteor" observations, he undertakes a detailed study of the the north-south and the vertical circulations within the counter-current and the neighbouring currents on both sides. The upper currents are separated from the deeper waters by a layer of transition within which the density increases so rapidly with depth that currents within the transition layer must be free from turbulence. The deeper layers are, therefore, not in communication with the upper. This feature and the character of the vertical circulations are of fundamental importance to the biological conditions of the region.

H. U. S.

H. B. Hachey. "The Effect of a Storm on an Inshore Area with Markedly Stratified Waters". Journ. Biol. Board Canada. Vol. I, No. 4. Toronto, 1935.

The author has studied the water masses found off the south coast of Nova Scotia at different times during the period June—October 1932. The stations at which observations were taken are within a distance of some eighty miles from Halifax harbour; the greatest depth at which investigation was made is 200 m. It was found that the waters were markedly stratified and that alterations in the stratification took place from time to time.

During the period of the investigations a three-day storm from a northerly direction occurred in September. The effect of the storm was analysed in various ways and it is stated that advance information of the approaching storm was given by marked changes in bottom temperatures and salinities occurring near the coast by Halifax harbour at depths of 20 m. and 50 m. about eight days before the storm began. After the storm subsided, the general trend was towards the conditions found before the storm.

The resulting movement of the water along the coast, accounted for

by the gradients of density in the sea, is found to have been 0.4 nautical miles per day in south-westerly direction. According to the topography of the surface — Fig. 2 in the paper — one would imagine the velocity of the movement to have been somewhat greater.

As to the stratification of the water the author distinguishes between an upper layer of salinities less than 32.00 $^0/_{00}$, an intermediate layer of salinities between 32.00 and 33.50 $^0/_{00}$, and a bottom layer af salinities greater than 33.50 $^0/_{00}$. By means of that classification the general arangement of the water is described. From the values given in the tables it appears that the water masses of salinities greater than about 32.50 $^0/_{00}$ are of a persistent nature — the water masses are represented by a nearly straight line in a TS-diagram — and that the water masses of salinities less than about 32.50 $^0/_{00}$ may possibly be mixing products of different kinds of surface water with the water of salinity about 32.50 $^0/_{00}$ at about 50 m. The mixing of the water masses from the surface to 50 m. depth was increased by the storm, whereas the water of salinity greater than 32.50 $^0/_{00}$ was in the main unaltered.

J. P. Jacobsen.

J. R. Lumby. "Salinity and Temperature of the English Channel." Ministry of Agriculture and Fisheries. Fishery Investigations. Series II, Vol. XIV. No. 3, London 1935.

This report is of great interest as it represents the first attempt to apply rigid and logical statistical reasoning in the presentation and study of hydrographic data. The author particularly emphasizes the method of presentation of the data and their "statistics". These are given in such a form that they are immediately available for comparison among themselves and for combination and comparison with data which may be collected subsequently. Further, efficient estimates of variation are appended in all cases, this rendering it quite a simple matter to test such comparisons by statistical methods. The report includes a historical summary of previous methods of collection and treatment of hydrographic data. A description of the methods now employed for collecting data is also included, with a critical examination of possible sources of error. The adequacy of "statistics" such as the monthly and annual means as representative values is discussed, and methods are developed for using the data so that they yield such statistics with the lowest possible standard error.

Of special interest is the "reiterative process" of Professor R. A. Fisher which is here applied for the first time. This process makes the most accurate allowance possible for gaps in a series of observations in the very numerous cases in which the existence of such gaps gives undue weight to the periods which are well represented by data. Mr. Lumby is rightly critical of a usage which is rather often found in the treatment of hydrographic data. I refer to the rejection of "aberrant" observations, without a reasonable criterion for judging such aberrancy. The "normal" salinity and "normal" temperature over any period seem in some cases to be mere abstractions, and apparent abnormalities do not as a rule indicate erroneous observations. They are real and call for explanation, not for rejection.

With the report is included a very fine atlas giving the mean isohalines and isotherms for each month over the whole period 1903—1927. From this it would be easy to see whether the observations in any month and year are below or above the average. The author, however, is emphatic that a series of observations above or below the average is not necessarily *abnormally*

high or *abnormally* low since there may be no single normal temperature or salinity. The absence of a "norm" may be due partly to a secular "trend" and partly to harmonic variation. The latter is of course clearly present in the annual variation in temperature. To test, however, for long period variations in temperature or salinity would necessitate observations extending over many such periods; such observations do not yet exist.

In general, the report is an admirable exposition of modern methods for extracting all available information from data relevant to means and their precision; this, without straining or distorting the data in any way. Mr. L u m b y is to be congratulated on his lucidly clear presentation of a viewpoint which appears to be new in hydrography and which no hydrographer can afford to neglect. Mr. L u m b y gives some space at the end of the report to the question of interpretation of the salinity and temperature conditions in the Channel which his data show. The treatment of this question is, however, very brief and the author evidently intends to elaborate this section of the work in a future report.

H. J. B. W.

A. E. Parr. "Report on hydrographic observations in the Gulf of Mexico and the adjacent straits made during the Yale Oceanographic Expedition on the "Mabel Taylor" in 1932." Bull. Bingham Oceanogr. Collect., Vol. V, Art. 1. New Haven, 1935.

Der Golf von Mexiko gehörte bislang zu den am schlechtesten erforschten Gebieten des Atlantischen Ozeans, was allein aus der Tatsache erhellt, dass brauchbare Salzgehaltsbestimmungen aus seinen Tiefen überhaupt nicht vorlagen. Die Yale Universität hat sich daher durch die Aussendung der Expedition auf dem Schuner "Mabel Taylor", die ca. 70 Stationen mit Reihenmessungen (im Maximum bis 3500 m. Tiefe) im Februar—April 1932 durchführte, ein grosses Verdienst erworben und ein modernes Beobachtungsmaterial von Temperatur und Salzgehalt, das zwar leider wegen des Verlustes der druckungeschützten Thermometer nicht streng auf die wahre Tiefe reduziert werden konnte, für den Golf von Mexiko bereitgestellt. In der vorliegenden Diskussion der Messungen beschränkt sich A. E. P a r r in der Hauptsache auf das spezielle Problem: Welche Beziehungen bestehen zwischen den Wassermassen des eigentlichen Golfes und denen der peripheren Yukatan- und Floridastrasse? — ein Problem, das er im wesentlichen durch eine qualitative Analyse der thermo-halinen Vertikalkurven (Beziehungskurven $S = f(t)$) zu lösen sucht. So wertvoll diese Beziehung Temperatur-Salzgehalt für das Verständnis der Mischungsverhältnisse im Meere ist, so sehr muss man sich nach Ansicht des Referenten davor hüten, aus ihr zu viel herauszulesen und an ihr Fragen des Wassertransportes zu entscheiden. Hierzu ist es noch erforderlich, die Profile nach den Methoden von B j e r k n e s, S a n d s t r ö m und H e l l a n d - H a n s e n dynamisch zu bearbeiten, eine Aufgabe, die P a r r für den Golf noch nicht in Angriff nimmt. P a r r gelangt zu dem Ergebnis, dass in die Strasse von Florida im wesentlichen nur "Karibisches Wasser" auf dem denkbar kürzesten Wege von der Yukatanstrasse her gelangt, und dass eigentliches "Golfwasser" nur oberflächlich in geringen Spuren an der linken Flanke des Floridastromes auftritt. Nach P a r r ist also der Floridastrom in der thermo-halinen Zusammensetzung seiner Hauptwassermassen unabhängig vom eigenlichen Golf von Mexiko und verdient es im Grunde gar nicht, "Golfstrom" genannt zu werden, eine Auffassung, die schon früher von N i e l s e n vertreten wurde. Nach Ansicht

des Referenten müssen für die Benennung des Stromes dynamische Überlegungen entscheidend sein: der Strom durch die Floridastrasse ist die gewaltige meridionale Abflussströmung des Golfes von Mexiko, die sich infolge der starken Gradientkräfte gegen die vorherrschenden Winde nach Norden durchsetzt, während bis zur Yukatanstrasse die Wasserbewegung des Nordäquatorial- und Karibischen Stromes stark beherrscht wird von der zonalen Passattrift. Ferner geht aus den Karten Parr's (besonders Fig. 8, 9, 11 und 12) klar hervor, dass der Karibische Strom einen wenn auch schwächeren Ausläufer nach NNW. entsendet, dessen Wassermassen — natürlich unter Vermischung mit eigentlichem Golfwasser — sicherlich zum Teil auf der Ostseite des Golfes wieder zum Hauptstrom zurückkehren. Wenn also auch die Hauptmasse des Floridastromes aus karibischem Wasser besteht, so empfängt er nach Ansicht des Referenten dieses nicht nur auf dem kürzesten Wege, sondern auch auf dem Umwege durch den Yukatan-Ausläufer über die östliche Hälfte des Golfes von Mexiko. Auf jeden Fall weist dieser Teil des Golfes eine Zirkulation der Wassermassen auf, welche dem Golfstromsystem zugerechnet werden muss. So sprechen dynamische Überlegungen — und überdies der historische Gesichtspunkt — dafür, den weltbekannten Namen "Golfstrom" neben der speziellen Bezeichnung "Floridastrom" beizubehalten und — wegen der überragenden Bedeutung dieser Strömung — ihn nach wie vor auch auf den vereinigten Florida-Antillenstrom anzuwenden. Wenn wir also in manchen Punkten den Schlüssen Parr's nicht völlig zu folgen vermögen, so erblicken wir doch in seiner Studie einen sehr wertvollen Beitrag zur Ozeanographie des bisher wenig erforschten Golfes von Mexiko.

G. Wüst.

O. H. Wendler. "Die Oberflächenbewegungen des Guineastromes." Gerlands Beitr. z. Geophys. Bd. XLIV, H. 2. Leipzig, 1935.

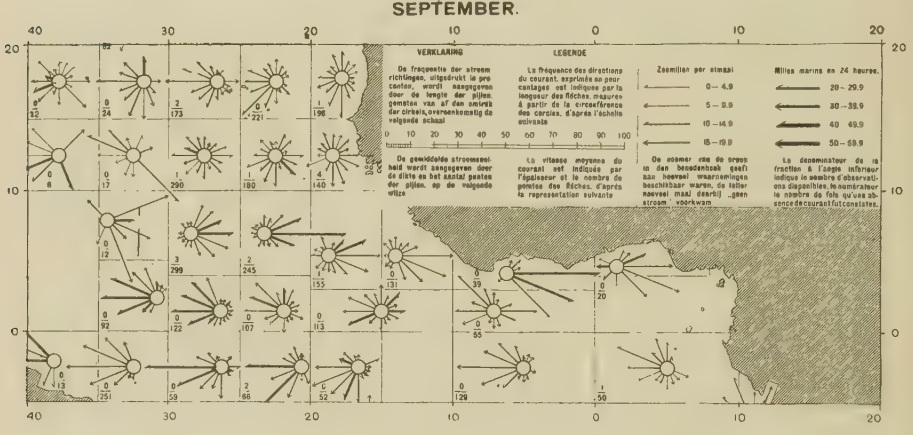
A. Schumacher. "Ueber Stromkabbelungen, besonders im Guineastrom und seiner Umgebung." Ann. d. Hydr. usw., LXIII Jahrg., H. X. Berlin, 1935.

Both these treatises are based for an important part on the large material which has been published by the Netherland Meteorological Institute in two oceanographic atlasses, No. 95: "Observations Océanographiques dans la région du courant de Guinée" (1904), et No. 110: "Observations Océanographiques dans l'Atlantique" (the latter completed 1931). It is gratifying to see that the enormous amount of labour which the observation and compilation of this material has necessitated is bearing fruit in the form of scientific investigations besides those mentioned above. The two papers complete each other in a very happy way. Wendler has tried to give a representation of the system of residual currents as much as possible in harmony with Bjerknes's hydrodynamical views, and he has utilized to this end principally the tables for one-degree squares belonging to the atlasses mentioned or provided in manuscript by the Netherlands Institute, completed by current observations from expeditions and unpublished maps for January—March by Merz, also based largely on the Dutch material. The result is shown in 12 current maps with lines of flow and lines of equal intensity, extending from 40°W. to 10°E. and 15°N. to 5°S. in which convergences and divergences, sinks and wells are clearly shown. In the lines of flow, four classes of "stability" of the current, 0—25 $^0/_0$ to 75—100 $^0/_0$, are indicated. The addition of four seasonal maps of prevailing

winds, also shown by flow lines and intensity lines, enables the reader to estimate the influence of the local winds on the current system.

In August and September, eastgoing currents extend between 4° and 10°N. from 30°W. to 0°. In April, the eastgoing currents are restricted to 3°—5°N. and 15°W.—5°E. In December and January the current follows the coast of Africa from 15°N.—0°W. In the intermediate months the system is more complicated.

W e n d l e r's conclusion is that the Guinea Current is mainly a compensation current, but that K r ü m m e l's experimental evidence for this explanation gives too simple a representation. In addition there is an important transfer of water from the region of the northern Equatorial Current to the southern one, partly directed along the coast, partly through the western part



of the Guinea Current. What W e n d l e r calls "Western Guinea Current" is frequently called Counter Equatorial Current, and we should like to adhere to this practice. W e n d l e r himself states that the origin of this current and several of its features are the same as with the counter equatorial currents in other oceans — and that its development is much smaller in the Atlantic Ocean may readily be ascribed to the much narrower space available. As a matter of fact, the two currents look like parts of one great current only in August and September.

The big changes in the development of both currents in the course of the year are to be ascribed to the varying influence of the local winds.

Though the curved arrows which interlink the regular current systems in W e n d l e r's maps indicate that whirls must form between opposite currents, they fail to indicate that on the borders of the regular systems and sometimes even in their central parts currents of another direction within an angle of 45°, and even opposite currents, may occur, owing to fluctuations in the big wind-system or local wind variations. We need only point to the reproduction of a part of our map of wind roses for September, where, for instance, the wind rose between 4°N. and the Guinea coast shows currents towards NE. and even towards SW.

It is exactly this feature which comes out strongly in S c h u m a c h e r's paper. The "Stromkabbelungen," the meeting places of conflicting currents,

for which Schumacher gives no less than 5 English translations, among which "current rips" seems the most suitable, are investigated by means of the Dutch material, supplemented by an English publication of 1874 (Official No. 20), a German-Dutch publication for one-degree squares in the Atlantic Ocean, and 1200 observations extracted from German logs.

Schumacher describes the instability phenomena occurring where currents of varying direction or velocity meet, and investigates their frequency as compared with the number of current and wind observations; he finds that the percentage of current rips shows a conspicuous maximum in the neighbourhood of the Guinea Current, both in the Dutch and the German observations. For 5 months, January, March, May, August, and October, he has also drawn current maps with small inset maps for prevailing winds, and in these maps dots indicate the places of current rips. It is interesting to compare Wendler's and Schumacher's maps, e. g., for August. In the main, the currents agree fairly well, though Schumacher's drawing does not suggest so much constancy as Wendler's. But the current rips, which Wendler's map would lead one to expect mainly in two narrow strips in latitudes 11° and 3°—5°N., are spread over an area from 0°—20°N., in greater concentration from 8°—16°. Evidently, position and intensity of the current-systems show big variations from year to year — the maps of residual currents show only one of the possible configurations.

Schumacher points out that the concentration of current rips in the neighbourhood of the Guinea Current emphasizes its character as a compensation current; in a drift current there is no reason for current rips, but if remote causes are responsible for the current, conflicts of currents of various origin may be expected.

The investigation of the special "remarks" from British sources does not lead to a very clear picture of the nature of the phenomenon, but it confirms the opinion that the local wind has little to do with it. Schumacher ends by recommending the study of current rips in other oceans also.

E. van Everdingen.

Alf Trolle. "M/S "Thor"s Havundersøgelsestogt 1934." Publ. om Østgrønland, Nr. 3. København, 1935.

It is very rarely that well-off people devote either their leisure or their surplus means to the pursuit of science, and still rarer that the sciences of the sea should represent the predilection of such enviable people as was the case with the late Prince of Monaco. But here is a Danish Prince of the High Seas offering us in a sumptuous trilingual volume a both spirited and detailed report of the voyage which the author undertook to Spitsbergen, the Greenland Sea, and Shiny Wall in a small Bohuslen smack of 40 feet (18 tons), with a 30 h.p. motor and a crew of six, including the Captain and the inevitable Tromsø ice-pilot.

Of the seven oceanographical stations one was near the Spitsbergen coast, four on the track between Reykjavik and Bergen, and two in the Greenland Sea. Interesting as the last-named may be, the most valuable results of this cruise seem to be the series of echo-soundings made on the voyage, although the gear seems to have been of a rather rough kind as the depths recorded are all given in round numbers. Capt. Trolle succeeded, however, in locating a very interesting area of rugged, supposedly volcanic, ground to the north of Jan Mayen, baptized "Thor"s Crater Bottom, and also in finding an elevation from deep water to the west of the Iceland

Ridge. Both discoveries are well indicated on the chart reproduced by the author under the title of "Østgrønlandshavet," from Nansen and Helland-Hansen's chart of the Norwegian Sea, a name evidently intolerable to Capt. Trolle.

No detail of equipment, no incident of the voyage has been left out of this record, a model of painstaking conscientiousness, and everything is given in three languages, except the end of the epilogue in Danish, which might be rendered thus: "It is the deed that draws me; I want to be a man of action, loving Life, especially on the High Seas, warring with the Elements, Face to Face with the great Master Builder and Maker."

O. S.

Mititaka Uda. "Distribution of drifting bodies in the ocean current." Bull. Japanese Soc. Sci. Fish. Vol. IV, No. 5. Tokyo, 1936.

Der Verfasser geht von Flaschenpostversuchen in japanischen Gewässern aus, bei denen man die Erfahrung machte, dass, je später die Flaschen aufgefunden wurden, desto mehr sich die Weglängen unterschieden, die sie zurückgelegt haten. Ohne zu verkennen, dass die Zeit des Auffindens nicht zugleich die der Ankunft der Flasche zu sein braucht, stellt der Verfasser die Fage, ob nicht auch die Scheindiffusion eine solche Wirkung haben muss, und behandelt diese Frage mathematisch. Indem er einen homogenen Strom voraussetzt, in den an einem Punkte Flaschen geworfen werden (Ähnliches gilt von Fischlaich usw.), macht er zwei verschiedene Annahmen, 1) dass ein Austausch nur in der Stromrichtung statthat, 2) dass er auch in der Richtung quer dazu vor sich geht. Die Lösung besagt, dass sich die Flaschen beim Vorwärtstriften zugleich ausbreiten, im Falle 1) in einer Geraden, im Falle 2) in einer sich mehr und mehr vergrössernden Ellipse, deren Achsen zu den zugehörigen Austauschzahlen proportional sind. Die Stärke der Ausbreitung hängt in beiden Fällen ab von der Wurzel aus der Zeit und vom Logarithmus der Zeit und stimmt in gewissem Grade zu den Beobachtungen. Sie weicht ab von dem Gesetze, dass Sutton für die Streuung kleiner Ballons in der Luft fand.

H. Thorade.

A. C. Hardy and **E. R. Gunther.** "The Plankton of the South Georgia whaling grounds and adjacent waters, 1926—1927." Discovery Reports, Vol. XI, pp. 1-456. Cambridge, 1935.

The three main objects in view in these investigations were:

1. "To find out which are the more important species in the plankton community and their relative abundance".
2. "To describe the actual distribution of these species at the time of the survey for comparison with surveys in later years."
3. "To obtain as far as possible a knowledge of the behaviour of the different organisms and the factors, physical, chemical and biological, governing their lives".

The report, which comprises some 450 pages, is too long for any adequate summary to be given here. Suffice it to say that the first two of these objects have been achieved in great detail and form a most valuable basis for the comparison of future surveys. The publication of the report has been delayed by unavoidable circumstances and mention should here be

made of two reports, on the phytoplankton by T. J. Hart (1) and the zooplankton by N. A. Mackintosh (2), which have been published earlier. These have given results of later work over considerably extended areas and have used the data of the present report as a basis for comparison.

The composition of the planktonic fauna and flora and their horizontal and vertical distribution have here been worked out in great detail and form a very valuable addition to our knowledge of the plankton in southern waters.

The report has been divided into five parts. For Part I., hydrology and methods, and Parts III. and IV. on the zooplankton, the authors are jointly responsible; Part II., on the phytoplankton, and Part V. on the plankton community, the whale fisheries and the hypothesis of animal exclusion, have been written by Professor Hardy.

This review concerns itself mainly with Part V., for in this section Hardy has elaborated a theory which must receive the considered thought of all concerned with problems of the sea. The other sections of the report have formed the main basis from which the theoretical conclusions have arisen, and in this connexion it is to be stated that Mr. Gunther is in complete agreement with the conclusions reached. The hypothesis in question is that for which Hardy has given the designation of "Animal Exclusion." It is briefly that a study of the interrelationship between zooplankton and phytoplankton gives evidence that under conditions of heavy diatom production the behaviour of many animals may be such that they are carried away from the area of diatom concentration in which presumably conditions are unfavourable. It is suggested that this modification in the distribution of the animals must be brought about by variations in their vertical distribution, and the detailed observations given in the other sections of the report are used as evidence. Previous observations by many workers on the inverse relationship between the abundance of plankton animals and plankton-feeding fish and that of the phytoplankton are reviewed. There can be two alternative hypotheses, one that the animals have avoided, or been excluded by, the abundant phytoplankton, and the other that the phytoplankton crop has been reduced by feeding in areas where the zooplankton is abundant.

The results in this report show that most plankton animals, in widely differing groups, tend to be concentrated in those areas in which the phytoplankton is not at its densest. This correlation has been related also to the distribution of phosphates which are a guide to the extent of phytoplankton production. The animals were not found abundantly in areas of lowered phosphate content. There were, however, certain exceptions, three species of copepods, *Calanus acutus*, *Rhincalanus gigas*, and *Oithona frigida*, show no such correlation, appearing to be unaffected by dense phytoplankton; while the two copepods *Calanus simillimus* and *Drepanopus pectinatus*, and the mysid, *Antarctomysis maxima*, seem to prefer the regions of dense phytoplankton. In this connexion the studies on vertical distribution have shown that the first three species show little or no vertical migration, and are rarely taken in large numbers in the upper phytoplankton zones, while the latter two copepods are found higher in the water than any other species. All other animals, which appear to be excluded, show marked vertical migration. Professor Hardy has suggested an analogy between the vertical migrations of the plankton animals and the navigation of a balloon by rising and falling into strata of air moving at different speeds and in different directions. By a number of diagrams he has shown how a process of sorting of the zooplankton may take place

if different durations of time are spent at different levels in which the strength and direction of water movement varies. If the migration of animals upwards at night into the upper layers is curtailed by some factor coincident with, or caused by, dense phytoplankton the animals may be carried away by a prolonged stay in the deeper layers which may be moving at a different speed from those above.

These, then, are the essentials of the exclusion hypothesis. There is an alternative hypothesis. Harvey has recenty elaborated Castracane's original suggestion that the phytoplankton crop may be largely grazed down by the zooplankton. There is therefore the possibility that in regions where the zooplankton is abundant the crop is kept grazed to moderate dimensions; but in regions where the animals are scarce, the phytoplankton, which reproduces at a very quick rate, may soon be enabled to develop into extremely dense patches. Hardy considered the question of regulation of plant production by the animals in connexion with his results and came to the conclusion that he "found some evidence that the phytoplankton may indeed be in part controlled by *Euphausia superba*, but that there is an indication that the remainder of the macroplankton organisms and some of the Copepoda may be excluded."

In seeking confirmative evidence for the exclusion theory elsewhere Hardy has quoted the findings of Russell at Plymouth that many species of animals live higher in the water in July than earlier in the year. The suggestion is made that until July the phytoplankton in the upper layers has been thick enough to cause exclusion. It can, however, be safely stated that the dense diatom crop has disappeared by May, but the animals are deepest in June. In the waters of the Great Barrier Reef lagoon channel, also, where the opacity of the water is very similar to that off Plymouth, most of the animals avoid the surface layers, although compared with its abundance at time in temperate waters the phytoplankton is negligible.

These criticisms are brought in as a warning that the theory must not be universally applied, as Hardy himself realizes (3, p. 66). The theory thus becomes applicable only in those regions where excessive phytoplankton production occurs. In antarctic waters the density of the phytoplankton far exceeds that found in temperate regions, although the production of *Skeletonema* in estuarine waters may at times be excessive. The work of Hardy in collaboration with R. E. Savage also gives strong evidence that in some areas in the North Sea phytoplankton may be sufficiently dense to cause the herring to avoid them. Hardy has marshalled a large body of evidence that goes far to support the validity of the exclusion theory. The proof of the theory lies largely in the ability to show that the vertical migration of plankton animals is modified by the density of the phytoplankton in the uppers layers. Such a test should be possible in home waters.

Whatever the result of such a test the great value of the hypothesis at this stage lies in the fact that it has brought to the forefront a problem which should engage the close attention of plankton workers. There is much accumulative evidence that the interrelationship between zooplankton and phytoplankton is a problem requiring detailed study. In discussing the general problem of vertical migration the possible importance of the effects of feeding on the behaviour of the animals is raised. It is rightly pointed out that whether the animal is well fed or starved may determine its phototropic sign. Reference is made to experimental work by G. L. Clarke in which he found that adult *Daphnia* were mostly positively phototropic in dilute cultures of food, but negative when the culture medium was fresh or rich. This is a factor that might well bring about varitions in

the extent of vertical migration and keep the animals in deeper layers when food is abundant.

As a direct outcome of the above ideas a relation was shown between the abundance of the zooplankton and the distribution of the whales. A positive correlation was shown between the distribution of the Blue and Fin whales and their food *Euphausia superba*. On the above argument it was predicted that the whales would not be found in regions of lowered phosphate content and this was fully confirmed. Examination of the phosphate content of the water may thus give an index to the distribution of the whales.

Other interesting theories are put forward. It is for instance suggested that the poorness in the numbers of surface-living species of zooplankton, and the absence of pelagic larval stages of the benthonic fauna in the antarctic may also be attributed to the unfavourable environment produced by the richness of the phytoplankton. Speculation is taken a stage further when it is suggested that corals and other tropical animals have overcome the difficulty of plant versus animal by imprisoning the phytoplankton in the form of symbiotic algae. This is perhaps attempting to push the exclusion theory too far; but the author may well be forgiven for falling into the fault of all those who in seeking to establish the validity of a theory attempt to make of it a universal panacea. For as Hardy himself says, "These suggestions are only put forward in the hope that the critical consideration and likely rejection of new hypotheses may lead to fresh observations and experiments." Hypotheses are the seeds from which new knowledge grows; may these here put forward serve their purpose.

While stress has been laid in this review upon theoretical deductions, sight must not be lost of the great bulk of new data Hardy and Gunther have added to our knowledge of southern plankton.

The report should be read by all concerned with marine biology. It has to the reviewer at any rate produced a profound impression on the possibilities of the new ecological aspect that has been opened in oceanic plankton investigation and given much food for thought.

F. S. R.

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1. Hart, T. J. 1934. On the Phytoplankton of the South West Atlantic and the Bellingshausen Sea 1929—31. Discovery Reports, Vol. VIII., pp. 1—268.
2. Mackintosh, N. A. 1934. Distribution of the macroplankton in the Atlantic Sector of the Antarctic. Discovery Reports, Vol. IX., pp. 65/160.
3. Hardy, A. C. 1936. Plankton Ecology and the hypothesis of animal exclusion. Proc. Linn. Soc. London, Sess. 148, 1935—36. Pt. 2, pp. 64—70.

E. Ehrenbaum. "Naturgeschichte und Wirtschaftliche Bedeutung der Seefische Nordeuropas." Handb. Seefisch. Nordeuropas. Herausgeg. von H. Lübbert und E. Ehrenbaum. 276 Text-Abb., 26 Tafeln, 2 Tabellenbeilagen. E. Schweizerbart'sche Verlagsbuchhandlung Stuttgart, 1936. Preis brosch. RM. 44. In Buckram gebunden RM. 47. Auslandspreis brosch. RM. 33. In Buckram gebunden. RM. 35.25.

This is the second volume (of ten) of the great work on the Sea Fisheries of Northern Europe published by the E. Schweizerbart'sche Verlagsbuchhandlung, of Stuttgart, under the editorship of Lübbert and Ehrenbaum.

The author of this volume, Professor Ehrenbaum, is well known to all concerned in scientific investigations into problems affecting the sea

fisheries of Northern Europe. He is undoubtedly the leading authority in the world on such subjects. His name alone is a sufficient guarantee of careful research, accurate presentation of facts and judicial summing-up of all the questions affecting the fisheries of the North and neighbouring seas.

We therefore turn to this volume with more than ordinary interest, as the subject dealt with by Professor E h r e n b a u m, "The Natural History and Economical Importance of the Sea Fishes of the Northern Europe," is perhaps the most important of all those dealt with in this series of monographs.

In the first place a very casual survey proves that the book is well illustrated, with 276 figures of fish, fish-eggs and larvae, maps and diagrams elucidating the essential features of the appearance and life history of our marine fish, both those of economic importance and those which by their rarity are not found in our markets. The illustrations of the adult fish are well selected, being both clear and bold; and the life history of such fish as the cod, eel, herring, mackerel, and plaice is clearly portrayed.

All the different species of fish found in Northern European waters are described and classified, though naturally those of economic value are treated in greater detail. No one who reads the sections devoted to such fish as the herring, cod, eel, or plaice can fail to be struck by the masterly way E h r e n b a u m has treated the subject. In the case of all economically valuable fish he gives not only a full and detailed account of the distribution and life history, but he also summarizes in a remarkably concise and clever fashion such points as artificial culture, transplantation, migration, scale-readings, fluctuations in size-limits of certain stocks and the question of "races" of fish, e. g., the herring and plaice. With regard to the life history of all fish of economic importance there will be found in addition full details of the spawning habits and spawning grounds, the eggs, larvae, and rate of growth; in fact everything essential to a correct appreciation of the bionomics of the species.

The question of overfishing is also dealt with in a moderate and temperate manner. E h r e n b a u m is a master in the art of presenting statistics so that all vital points are easily intelligible, even to the non-expert reader. In all controversial matters it may fairly be said that he has adopted a judicial and not a polemical attitude.

There can be no question but that this book will be for many years the standard work on our marine fish.

While each reader will no doubt decide for himself what part of the book he particularly admires we should like to point out what are, in our opinion, the outstanding features.

The herring is described on pages 9—22. Within this brief compass the author has succeeded in compressing all the essential facts not only in the life history of the fish, but also its economic importance in the fisheries of Northern Europe. With his flair for selecting the essential E h r e n b a u m gives on the top of page 20 an illuminating table of the statistics of the herring catch of the chief nations engaged in this fishery. In 1913 England caught 371.5, Norway 293.2, Scotland 226.0, Holland 104.9, and Germany 59.5 million kilogrammes. In 1932 the totals were: Norway 587.1, Scotland 146.0, Germany 120.6, England 121.1, and Holland 66.5 million kilogrammes. This is a stupendous change and is due to other reasons than the courage, enterprise, and vigour of the fishermen of the various nations concerned.

Take the eel as another example. On pages 50 to 58 E h r e n b a u m gives what is, in our opinion, the best succinct account yet written of one

of the romances of modern scientific investigation. Here as elsewhere the illustrations help the text, so that he who runs may read.

The cod is described on pages 94—104. Here again is an up-to-date, accurate, precise, and sufficient record of a fish which has increased rapidly in the public favour during the last few years. In 1913 the total European catch was 704,809 tons; in 1930 it was 1,137,734 tons. The British catch has increased from 197,078 tons in 1913 to 249,216 tons in 1930.

Norway, the other large catcher of cod, shows a slight decrease from 359,249 tons in 1913 to 352,805 tons in 1930.

The account of the plaice is a model of brevity and lucidity (pp. 208—214). It is true that this fish is falling off in popular esteem, particularly in England, where a fish large enough for filleting is desired. So that as Ehrenbaum correctly and pertinently remarks, the plaice is no longer the "Sorgenkind" of the North Sea.

Similar full and detailed accounts are given for other important fish, notably the mackerel and haddock.

When we turn to the rarities and recent discoveries we find many of great interest. For instance, the very rare *Chlamydoselachus* is described (p. 273). The rarer families such as the *Macruridae* and *Scopelidae* are adequately dealt with. One or two of the most recent additions to the British fauna are, however, omitted, notably *Istiophorus americanus* recently recorded by Norman.

In conclusion we have carefully searched the book for errors and found none. Professor Ehrenbaum is warmly to be congratulated on the addition of a notable work to the *Handbuch der Seefischerei Nordeuropas* and to the literature of fish and fishing in general. In our opinon the book will at once attain first rank in the list of works devoted to fishery problems and will remain for a long time a work to be consulted and read not only by experts, but also by all who would be conversant with an industry of the greatest importance to the maritime nations of Northern Europe.

It is equally certain that this book cannot be ignored by those who are responsible for the administration of the sea fisheries in the various countries, since such administration if it is to be effective, must be based on a sound and thorough knowledge of the subject, and this knowledge can be obtained nowhere else in such brevity and clarity as in this volume.

J. T. J.

F. S. Russell. "On the Value of Certain Plankton Animals as Indicators of Water Movements in the English Channel and North Sea." Journ. Mar. Biol. Assoc. N. S., Vol. XX, No. 2. Plymouth, 1935.

The chance finding of a newly stranded oceanic organism such as *Velella*, *Ianthina* or *Physalia* gives a momentary thrill to the discoverer and arouses a wish to know whence and how the stranger has come to our shores. These conspicuous objects, however, being at the mercy of winds and surface drift, attract far more notice than their importance deserves, and in the present paper M. Russell directs our attention to a number of humbler forms which can furnish more reliable information of their place of origin.

Starting with two species of *Sagitta, S. elegans* and *S. setosa* which occur alternatively off Plymouth, he has worked out their mutually exclusive distribution round the coasts of Great Britain and Ireland, and has been able to show that *S. elegans* is characteristic of water to the west and south of Ireland, with a range extending round the north of Scotland, while *S. setosa* is a neritic form, inhabiting the eastern Channel and southern

North Sea, whose western limits in the Channel fluctuate up and down in unison with the flooding or, as some would say, transgression of "western" water into the mouth of the Channel, and the correlated slackening of the flow from the north of Atlantic water into the North Sea.

Besides the two types of water thus characterized, there are indications that a third type, coming from the south-west, may make its way to the mouth of the Channel. The copepod *Euchaeta hebes* and the siphonophore *Muggaea atlantica* and, on less reliable grounds, the pelagic tunicates, are suggested as indicators of this water.

The value as indicators of several other species, belonging to many different groups and all of a size that can readily be recognized, is discussed in the paper and their association with different types of water recorded. Together with *Sagitta elegans* are found the medusae *Aglantha rosea*, *Stephanomia bijuga*, and *Liriope exigua*, the pteropod *Clione limacina* and, in very small numbers, another species of *Sagitta*, *S. serratodentata*. *Sagitta setosa*, on the other hand, has no companion of an equivalent size, though doubtless fine-meshed nets would furnish minute species with a similar distribution.

The interaction of the three types of water mentioned have been worked out on broad lines for the Plymouth area by Mr. Russell, but many details still require to be filled in, even for that well-known area, and a wide field for the application of similar methods to other localities still remains unworked.

The author has made considerable use of the reports of the plankton investigations carried out by the International Council during the early years of its existence, and his paper shows how such data, put aside for a while, may, in the light of fresh knowledge, prove of very great value.

G. P. F.

F. S. Russell. "The Seasonal Abundance and Distribution of the Pelagic Young of Teleostean Fishes Caught in the Ring-Trawl in Offshore Waters in the Plymouth Area. Pt. II". Journ. Mar. Biol. Assoc. N.S., Vol. XX, No. 2. Plymouth, 1935.

This paper gives an account of the post-larval fishes taken off Plymouth in weekly hauls from bottom to surface with a 2-metre stramin net during the years 1930-34. It is a continuation of an account of similar hauls made during 1924-29, which was reviewed in Vol. VI, No. 1 of this journal. The data relate to fifty different fishes, most of which only occurred on very few occasions.

Taking those fishes whose numbers were sufficient for statistical treatment, it was found that for no fish in 1930-34, excepting herring, did the best year exceed the average by more than three times nor the worst fall short of it by more than one-fifth. This range, though considerable, is far smaller than the estimated variation in the relative abundance of the year-classes in many commercial fishes. Herring totals, however, in 1932 were seventeen times higher than in the next highest year, 1933.

Taking the whole period 1924-34, it appears that for the early spawning species, mainly boreal in their distribution, the year 1929 showed a distinct shortage and the period 1924-29 was one of deficiency. The summer-spawning fish, *Arnoglossus spp.*, mackerel, and gobies, on the contrary, showed no shortage in 1929, and the suggestion is made that the presence of shoals of ctenophores in the spring of that year may have been, directly or indirectly, the cause.

Mr. Russell suggests that the winter supply of phosphate off Plymouth may have an influence on the abundance of the summer-spawning fish, the two years 1924 and 1926 being characterized by large numbers of the larvae of summer spawners and by waters of a high phosphate content in the previous winter. The basal cause of the variations in phosphate may be looked for in the influx of Atlantic water.

A correlation is noted between the landings of whiting from two distinct sources, British and French, in the Channel and the number of post-larvae in the collections. Both show a period of low productivity in 1925-30 followed by an increase in abundance up to 1933, the inference being that large numbers of spawners produced a large brood. A clear relationship is also noted between the date of the rise of water temperature and the date of the maximum abundance of young whiting.

These and a few other deductions, useful suggestions as they are, may seem a small return for the tedious routine of sorting and naming of numerous collections over many years, but, in addition, we have the valuable result that it is now possible to point to a normal yield for each month, taken by a standard method, with which collections made in future years may be compared.

G. P. F.

S. S. Flower. "Further Notes on the Duration of Life in Animals. I. Fishes: as determined by Otolith and Scalereadings and Direct Observations on Living Individuals." Proc. Zool. Soc. London. Part. 2, pp. 265—304. London, 1935.

We are often asked how long a fish will live and Major Flower has taken the trouble to find the answer. This has necessitated consulting 86 published papers, listed in his bibliography, and correspondence with observers all over the world. The result is information about more than 120 species, and it is obvious that what is given has been most carefully checked. To take a bizarre example: at Tain in Ross-shire in Scotland there is an eel which has been kept in the family of the Registrar of Births, Marriages, and Deaths — careful people — for more than 40 years. Its accommodation has been increased from the original jam-jar to an accumulator jar, and its unvaried diet has been an occasional worm.

The author finds evidence of 40 species living more than 10 years. Only 5 species have been authentically recorded as exceeding 40 years span, namely the catfish *Silurus glanis*, the European and American eel, the mirror carp and the sterlet. Some gobies and the ice-fish *(Salanx)* of China live for less than a year.

On the theoretical side, it seems to the author that senility does attack fish. He has also colleced opinions that the giants we occasionally encounter are not necessarily old fish. The conception of unlimited growth and span of life is not seriously discussed and the implication is that this idea is not borne out. The reviewer has only one criticism of this praiseworthy work. The author has not made sufficiently clear the difference in effect of natural and violent death on the span of life. In good aquaria, after acclimatization, only senility can strike. In the sea or river there are also natural enemies. In heavily fished waters there is also Man. The spans given in the summary are, therefore, not comparable and some distinction might have been made according to how the information came. In the body of the paper, of course, all proper information is given.

M. G.

R. Hile. "Age and Growth of the Cisco *Leucichthys artedi* (Le Sueur), in the Lakes of the Northeastern Highlands, Wisconsin." Bull. Bureau of Fisheries, Vol. XLVIII, pp. 211—317, (Bull. No. 19), U. S. Dept. Commerce. Washington, 1936.

This paper deals with the cisco (lake herring) population of four relatively small lakes, fairly close to Lakes Michigan and Superior in the summers of 1928 and 1930 to 1932. Age was estimated from the scales of 3,882 fish and growth-rate was calculated in 3,694 of them.

Trout, Muskellunge, Silver, and Clear Lakes were selected, as they differ in the amount of fixed CO_2 present (taken as an index of productivity). Two other lakes (Allequash and Tomahawk) are dealt with in a short appendix. There is no commercial fishery in these lakes and the material came from experimental fixed gill-nets fished on the bottom. The mesh varied from $1^1/_4$ to 3 inches, and the nets were 50 yards long by 6 feet deep. The gear was renewed in 1931.

In the calculation of l_1, l_2 etc. from the scales, Lee's phenomenon (decrease of l_1 with increasing age) was found mainly in Silver Lake. A correction, resembling Lee's correction for length prior to scale-formation, reduced but did not eliminate the phenomenon, which is due to an actual decrease in v_1 (scale-size at 1st ring) and not to a change in the proportion fish/scale. This is attributed to selection, not by nets, but more probably by differential vertical distribution according to size (the nets being on the bottom), or owing to better survival of slow-growing fish.

The (calculated) length growth-curves show that the mean size for age varies in the four lakes, which, in order of increasing size, are T, S, M, C, (initial letters). The percentage length-increments, however, are similar in all four lakes and are low after the fourth year. The mean weight for age also varies in the ascending order T, M, S, C♂, C♀.

Growth in length and weight is compared with growth of this species in other waters, including the Great Lakes and Hudson Bay. Growth in Trout and Clear Lakes resembles the poorest and best growth elsewhere; but a diagram would have demonstrated this more plainly.

In three lakes the length distributions of different age-groups overlap very much, even in the younger age-groups, but in Clear Lake there is better separation. The author remarks (p. 234) that length is therefore a poor index of age, but he seems to maintain the opposite view later (p. 292).

Twelve pages are given to condition and the length-weight relation. The former is given by K in the equation $W = K \times 10^{-5}L^3$, and the latter is described by the equation $W = CL^n$ (where W = weight, L = length, C = a constant, and n is determined empirically). Much of this space is devoted to what appears to be a thorough trouncing of previous workers in this field for their mathematical malpractices and ineptitude in confusing these two issues. The uninitiated will perhaps be comforted by the knowledge that the author brackets condition with fatness (p. 241). They are likely to be disappointed that he furnishes no data for so readily understandable an expression of condition. Condition improves with increasing length in Clear and Silver Lakes, but in Trout and Muskellunge Lakes it deteriorates.

For lack of a complete series of samples throughout the growing season its duration was estimated from the proportion which the current season's calculated growth (at time of capture) bore to the calculated growth of the same year-class for the whole year (as determined from later samples). Growth is supposed to begin in all lakes with the thaw in early May, but ends at different times from late July to early October (in the order T, M, S, C.)

The cisco is apparently a bottom-living fish with a preference for cool water, but it may be driven into shallower and warmer water in summer by lack of oxygen at deeper levels.

In Clear and Trout Lakes oxygen is not deficient in deep water and the fish are not confined to one stratum of water (i. e., the lowest and coolest with sufficient O_2) as in Muskellunge and Silver Lakes.

The most probable order of the lakes in respect of population density throughout the growing season is T, M, S, C. (maximum to minimum). This is fairly similar to their order of productivity (bound CO_2) and is the reverse of their order of growth in length and weight. Growth is probably diminished by intense competition for food or by crowding *per se*, but population density may depend on larval feeding conditions, as the lakes follow much the same order in respect of population as of organic content of the plankton. The order in respect of condition and longevity are the same (C, S, T, M: maximum to minimum) and the reverse of that for organic content of plankton.

Good and bad year-classes do not occur in the four lakes simultaneously. As none are further apart than 18 km., local factors rather than general climatic conditions must be responsible.

Maturity often occurs in I-group, and always in II-group fish, though in other waters it may not appear till the III or IV-group. Spawning occurs in late autumn and the eggs hatch in the following spring. The proportion of females always rises with age and they outnumber the males (save in Clear Lake up to group VI). Lower viability of the males accounts for the increasing excess of females (C, S, M, T) with increasing population density. The author does not explain this lower viability, and only in Clear Lake are the females heavier than the males.

Net selection occurs, and though size of mesh and mean size of fish caught vary together, any given mesh acts differently on the four stocks, catching progressively larger fish in the order T, M, S, C. Although two nets of different mesh may catch fish differing little in mean size, one may be more efficient and catch a greater number of them. Net selection is therefore less liable to vitiate estimates of an age-group's mean size than of its numerical abundance.

Dr. H i l e's paper is of great interest and is well and clearly, though sometimes diffusely, written. The data are full and tabulated, and there is a large bibliography. The use of figures rather than of tables would perhaps have been an advantage to the reader, and the symbol l_1 is a convenient abbreviation of "the calculated growth in length during the first year of life."

J. A. R.

Current Bibliography.

Prepared by the Editor with the assistance of Miss Thursby-Pelham.

NOTE. The scope of the Bibliography is limited in the main to the area covered by the Council's activities, but there are included papers of general interest relating to other areas in the North Temperate and Arctic regions and exceptionally elsewhere. Limnological references are not as a rule given, but papers relating to brackish waters and to salmon and freshwater fish studied by the Council are included.

The classification of entries follows in a general way that adopted in Dr. Allen's Selected Bibliography published in Vol. I, Nos. 1 and 2 of the Journal, and since reprinted (Price, 1 Kr.).

Subscribers and those on the distribution list will receive regularly upon application to the Administrative Secretary copies of the Bibliography printed on one side of the page only, for use in making up card indices.

The Editor will be glad to be advised of emendations and additions to the Bibliography.

Physical and Biological Conditions in the Sea.

GENERAL HYDROGRAPHY

Berg, L. S. Der Niveaustand des Kaspischen Meeres in historischer Zeit. Mitt. Geogr. Gesell., LXVIII, Nr. 5, Wien, 1935.

Brunelli, G. I pionieri della oceanografia. Boll. Pesca, Piscicolt. e Idrobiol., XI, 697—705, Roma, 1935.

De Buen, R. Liste Chronologique des Croisières Océanographiques. Manuel pour les observations océanographiques à la mer, I. Comm. Internat. p. l'Explor. Sci. de la Mer Méditerranée, Venezia, 1935.

Defant, A. Die wissenschaftlichen Ergebnisse der norwegischen Nord-Polar-Expedition auf der "Maud" 1918—25. Naturwissenschaften, I, Berlin, 1936.

Dwyer, J. N. Hydrographic bottle for fisheries survey. Trans. Amer. Fish. Soc., LXII, 342—43, New York, 1932.

Hachev, H. B. Transgressions in the Atlantic Ocean. Science, N. S., LXXXIII, 349—50, U. S. A., 1936.

Loewe, F. Hydrographische Untersuchungen in Fjorden Westgrönlands. Arctica, III, U. S. S. R., 1935.

Mangor, I. C. The state of the ice in the arctic seas 1935. Publ. Danske Meteor. Inst. Medd. Aarbøger, København, 1936.

N. America. Proceedings 1921—30. N. American Council on Fish. Invest., No. 1, Ottawa, 1932.

N. America. Proceedings 1931-1933. N. Amer. Council on Fish. Invest., No. 2, Ottawa, 1935.

Pettersson, H. Recent Oceanographic Research in Sweden. Gøteborgs Högskolas Årsskrift, XXXIX, 207-18, Gøteborg, 1933.

Schokalsky, J. Recent Russian Researches in the Arctic Sea and in the Mountains of Central Asia. Scottish Geogr. Mag., LII, 73-84, Edinburgh, 1936.

Schulz, B. Die Ergebnisse der internationalen hydrographischen Beobachtungen im Kattegat im August 1931. Cons. Perm. Internat. p. l'Explor. de la Mer. Rapp. et Proc.-Verb., XCV, 49-61, Copenhague, 1936.
Sewell, R. B. S. Introduction and List of Stations. John Murray Exped. 1933-34. Sci. Rep. Brit. Mus. (Nat. Hist.), I, No. 1, London, 1935.
Stocks, T. und Wüst, G. Die Tiefenverhältnisse des offenen Atlantischen Ozeans. Wiss. Ergebn. deutsch. Atlant. Exped. a. d. Forsch- und Vermessungsschiff "Meteor", 1925-27, Bd. III, Teil I, Berlin und Leipzig, 1935.
Uda, M. Results of simultaneous oceanographic investigations in the Japan Sea and its adjacent waters during October and November, 1933. Journ. Imp. Fish. Exper. Stat., VII, 91-151, Tokyo, 1936. (In Japanese, English résumé).

Physics and Chemistry of Sea Water.

Brunelli, G. Problemi di biologia marina con particolare riguardo alla ittiologia. Boll. Pesca, Piscicolt. e Idrobiol., XI, 801—11, Roma, 1935.
Möller, L. Gewinnung von Bodenwasserproben mit Hilfe von Richterschen Glaswasserschöpfern. Arch. Hydrobiol. et d'Ichthyol., XXVIII, Poland, 1935.
v. Schubert, O. Die Stabilitätsverhältnisse des Atlantischen Ozeans. Wiss. Ergebn. deutsch. Atlant. Exped. a. d. Forsch.- und Vermessungsschiff "Meteor", 1925-1927, Bd. VI, Teil II, Berlin und Leipzig, 1935.

TEMPERATURE AND SALINITY

Becker, R. Über den jährlichen Temperaturgang auf dem Atlantischen Ozean. Ann. der Hydrogr. usw., LXIV, 198—203, Berlin, 1936.
Dakin, W. J. and Colefax, A. N. Observations on the Seasonal Changes in Temperature, Salinity, Phosphates, and Nitrate Nitrogen and Oxygen of the Ocean Waters on the Continental Shelf off New South Wales and the Relationship to Plankton Production. Proc. Linn. Soc. N. S. Wales, LX, 303—14, Sydney, 1935.
Dietrich, G. Aufbau und Bewegung von Golfstrom und Agulhasstrom. Naturwissenschaften, I, Berlin, 1936.
Gamba, P. Sulla temperatura superficiale dell'acqua del mare nei suoi rapporti con l'afflusso idrico dal retroterra e con le condizioni meteorologiche locali. Mem. del R. Ufficio Cent. di Met. e Geofis., Ser III, V, Roma, 1935.
Johansson, O. V. Die Temperaturverhältnisse Spitzbergens (Svalbard). Ann. der Hydrogr. usw., LXIV, 81—96, Berlin, 1936.
Kimura, K. Hydrographical Observation near Awasima Isle situated at the Northeastern End of Suruga Bay. (Further Note II). Variations of and Mutual Relations among Water Temperature, Salinity and Transparency. Bull. Japan. Soc. Sci. Fish., IV, 339—52, Tokyo, 1936. (In Japanese, English résumé).
Kuhlbrodt, E. Schleuderthermometer für Bordgebrauch. Ann. der Hydrogr. usw., LXIV, 57—60, Berlin, 1936.
Lotze, F. Die Herkunft der Salze im Weltmeer. Natur und Volk, LXVI, 71—78, Frankfurt a. M., 1936.
Mitchell, P. H. and Taylor, I. R. The Dissociation Constant of Cresol Red in Sea Water. Woods Hole Oceanogr. Inst., No. 74, 169—72, U. S. A., 1935.
Scherhag, R. Eine bemerkenswerte Klimaänderung über Nordeuropa. Ann. der Hydrogr. usw., LXIV, 96—100, Berlin, 1936.
Strand, E. und Ozolins, V. Hydrographische Untersuchungen der Hydrobiologischen Station im Rigaer Meerbusen und im Baltischen Meere. VII. Folia Zool. et Hydrobiol., VIII, 288, Riga, 1935.
Wegener, K. Zur Verdunstung. Ann. der Hydrogr. usw., LXIV, 204—06, Berlin, 1936.

PHOSPATES AND NITRATES

Dakin, W. J. and Colefax, A. N. Observations on the Seasonal Changes in Temperature, Salility, Phospates, and Nitrate Nitrogen and Oxygen of the Ocean Waters on the Continental Shelf off New South Wales and the Relationship to Plankton Production. Proc. Linn. Soc. N. S. Wales, LX, 303—14, Sydney, 1935.
Riddell, W. A. The reduced strychnine method for determining nitrates in sea water. Journ. Biol. Board Canada, II, 1—11, Toronto. 1936.

OTHER CONSTITUENTS

Atkins, W. R. G. The Estimation of Zinc in Sea Water using Sodium Diethyldithiocarbonate. Journ. Mar. Biol. Assoc. U. K., N. S. XX, 625—26, Plymouth, 1936.

Hernegger, F. and Karlik, B. Uranium in Sea-Water. Medd. från Gøteborgs Högskolas Oceanogr. Inst., No. 12, Göteborg, 1935.
Keys, A., Christensen, E. H. and Krogh, A. The Organic Metabolism of Sea-Water with special reference to the Ultimate Food Cycle in the Sea. Woods Hole Oceanogr. Inst., No. 79, 181—96, U. S. A., 1935.
Maldura, C. M. Gli equilibri dell'acido carbonico e l'alcalinità delle acque lagunari. Boll. Pesca, Piscicolt. e Idrobiol., XI, 812—25, Roma, 1935.
Rakestraw, N. W. and Mahncke, H. E. Boron Content of Sea Water of the North Atlantic Coast. Indust. and Engin. Chem., VII, 425, Easton, Pa., 1935.
Seiwell, H. R. The Annual Organic Production and Nutrient Phosphorus Requirement in the Tropical Western North Atlantic. Woods Hole Oceanogr. Inst. No. 24, 20—32, U. S. A., 1935.
Seiwell, G. E. Note on Iron Analyses of Atlantic Coastal Waters. Ecology, XVI, 663—64. New York. 1935.

Currents.

Anon. An advance in sea-survey and fishery investigation. Mr. Buchanan-Wollastons unique self-recording current-meter. Fish Trades Gazette, 18, London, 11-IV-36.
Defant, A. Schichtung und Zirkulation des Atlantischen Ozeans. Dritte Lieferung. Die Troposphäre. Wiss. Ergebn. deutsch. atlant. Exped. a. d. Forsch.- und Vermessungsschiff "Meteor", 1925—1927, Bd. VI, Teil 1, Berlin und Leipzig, 1936.
Kimura, K. Hydrographical Observation near Awasima Isle situated at the North-eastern End of Suruga Bay. (Further Note III). Current. Bull. Japan. Soc. Sci. Fish., IV, 374—84, Tokyo, 1936.
Marmer, H. A. Tides and Currents in New York Harbor. U. S. Dept. of Comm. Coast and Geodetic Survey, Spec. Publ. No. 111, Washington. D. C., 1935.
Pettersson, H. and Målmheden, H. W. Eddy-Viscosity in Stratified Water. II. Medd. från Göteborgs Högskolas Oceanogr. Inst., No. 11, Göteborg, 1935.
Schulz, B. Das Bodenwasser und die Gliederung der atlantischen Tiefsee. Petermanns Mitt., LXXXII, 48—50, Gotha, 1936.
Sverdrup, H. U. Das maritime Verdunstungsproblem. Ann. der Hydrogr. usw., LXIV, 41—47, Berlin, 1936.
Tait, J. B. Fluctuations in our catches of Marketable Fish. Fishing News, 24—25, Aberdeen, 29-II-36.
Tully, J. P. Drift of the Japanese Current. Western Fish., XI, No. 2, 1935.
Uda, M. Distribution of Drifting Bodies in the Ocean Current. Bull. Japan. Soc. Sci. Fish., IV, 289—93, Tokyo, 1936.
Wüst, G. Die Tiefenzirkulation im Raume des Atlantischen Ozeans. Naturwissenschaften, XXIV, 131—33, Berlin, 1936.
Wüst, G. Die Gliederung des Weltmeeres. Petermanns Mitt., LXXXII, 33—38, Gotha, 1936.

Tides.

Anon. Liverpool Observatory and Tidal Institute, Ann. Rep. 1935. Liverpool, 1936.
Marmer, H. A. Tides and Currents in New York Harbor. U. S. Dept. of Comm. Coast and Geodetic Survey, Spec. Publ. No. 111, Washington, D. C., 1935.
Stenij, S. E. Wasserstandsangaben 1934. Merentut. Julk, No. 104, Helsinki, 1935. (In Finnish and Swedish, German résumé).
U. S. A. Manual of Tide Observations. Spec. Publ. U. S. Dept. of Comm., No. 196, Washington, 1935.
Zeilon, N. Experiments on Boundary Tides. Medd. från Göteborgs Högskolas Oceanogr. Inst., No. 8, Göteborg, 1934.

LIGHT, COLOUR AND TRANSPARENCY

Fontaine, M. La pénétration des rayons ultra-violets solaires dans le milieu marin. Bull. Soc. d'Océanogr. de France, XVI, 1521—527, Paris, 1936.
Kamiya, S. The visible distance of objects immersed in sea-water. I. Bull. Japan. Soc. Sci. Fish, IV, 265—73, Tokyo, 1936.
Kimura, K. Hydrographical Observation near Awasima Isle situated at the North-eastern End of Suruga Bay. (Further Note II). Variations of and Mutual Relations among Water Temperature, Salinity and Transparency. Bull. Japan. Soc. Sci. Fish., IV, 339—52, Tokyo. 1936. (In Japanese, English résumé).
Oster, R. H. and Clarke, G. L. The Penetration of the Red, Green and Violet Components of Daylight into Atlantic Waters. Journ. Optical Soc. of Amer., XXV., 1—16, Philadelphia, 1935.
Pettersson, H. Das Licht im Meer. Bioklim. Beibl., I, Braunschweig, 1936.

Oceanography-Miscellaneous.

Anon. The Woods Hole Oceanographic Institution Report for the Year 1934. Woods Hole, U. S. A., 1935.
Ekman, S. Tiergeographie des Meeres. Leipzig, 1935.
Fraser, C. M. Oceanography in British Columbia in 1934. Trans Amer. Geophys. Union, 16th Ann. Meet., 256—58, Washington, 1935.
Schmidt, W. Cause of "Oil Patches" on Water Surfaces. Nature, CXXXVII, 777, London, 1936.

Plankton.

Aikawa, H. A quantitative analysis of the plankton association in the adjacent seas of Japan. VI. Journ. Imp. Fish. Exper. Stat., VII, 153—82, Tokyo, 1936. (In Japanese, English résumé).
Bouxin, J. et Legendre, R. La Faune Pélagique de l'Atlantique recueillie dans des estomacs de Germons au large du Golfe de Gascogne. 2e Partie: Céphalopodes. Ann. Inst. Océanogr. Monaco, N. S. XVI, Fasc. 1, Paris, 1936.
Brunelli, G. Problemi di biologia marina con particolare riguardo alla ittiologia. Boll. Pesca, Piscicolt. e Idrobiol., XI, 801—11, Roma, 1935.
Clarke, G. L. and Gellis, S. S. The Nutrition of Copepods in Relation to the Food-Cycle of the Sea. Biol. Bull., Woods Hole, Mass., LXVIII, 231—46, U. S. A., 1935.
Dakin, W. J. and Colefax, A. N. Observations on the Seasonal Changes in Temperature, Salinity, Phosphates, and Nitrate Nitrogen and Oxygen of the Ocean Waters on the Continental Shelf off New South Wales and the Relationship to Plankton Production. Proc. Linn. Soc. N. S. Wales, LX, 303—14, Sydney, 1935.
Eriksson, S. Studien über die Fangapparate der Branchiopoden nebst einigen phylogenetischen Bemerkungen. Zool. Bidrag. fr. Uppsala, XV, 23—288, Uppsala, 1936.
Ercegović, A. Etudes qualitative et quantitative du phytoplancton dans les eaux côtières de l'Adriatique oriental moyen au cours de l'année 1934. Acta Adriatica Inst. Biol.-Oceanogr. Split, No. 9, Split, 1936.
Fraser, J. H. The distribution of rock pool Copepoda according to tidal level. Journ. Anim. Ecol., V, 19—22, London, 1936.
Gibbons, S. G. North Sea and its Rich Harvest. Food of our Fish: what Plankton is and what it means to successful Voyaging. Fishing News, 21—22, Aberdeen, 22—II—36.
Grave, C. Metamorphosis of Ascidian Larvae. Pap. from the Tortugas Lab., XXIX, 209—92, Washington, D. C., 1936.
Gurney, R. Notes on some Decapod Crustacea of Bermuda. I. The Larvae of *Leptochela* and *Latreutes*.. Proc. Zool. Soc., 1935, Part 4, 785—93, London, 1935.
Hardy, A. C. Plankton ecology and the hypothesis of animal exclusion. Proc. Linn. Soc. London, CXLVIII, 64—70, London, 1936.
Hardy, A. C. The continuous Plankton Recorder: a new Method of Survey. Cons. Perm. Internat. p. l'Explor. de la Mer. Rapp. et Proc-Verb., XCV, 35—48, Copenhague, 1936.
Hart, J. F. L. Culture methods for Brachyura and Anomura. Collecting Net, X, No. 87, 1935.
Hart, J. F. L. The larval development of British Columbia Brachyura. I. Xanthidae, Pinnotheridae (in part) and Grapsidae. Canad. Journ. Res., XII, 411—32, Ottawa, 1935.
Hentschel, E. Über das Winterplankton im Süden von Island. Cons. Perm. Internat. p. l'Explor. de la Mer. Rapp. et Proc.-Verb., XCIX, I, Copenhague, 1936.
Höglund, H. and Landberg, S. Further Investigations upon the Photosynthesis of Phyto-plankton by constant Illumination. Cons. Perm. Internat. p. l'Explor. de la Mer. Rapp. et Proc.-Verb., XCV, 31—34, Copenhague, 1936.
Holl, K. Freie Kohlensäure als Faktor für die Verbreitung der Plankton-Organismen. Arch. Hydrobiol. et d'Ichthyol,. XXIV, 301—04, Varsovie, 1932.
Ihle, J. E. W. und Ihle-Landenberg, M. E. *Cyclosalpa virgula* (Vogt) und *Cyclosalpa Komaii* n. sp. Publ. Staz. Zool. di Napoli, XV, Fasc. 2, 274—83, Roma, 1936.
Iida, T. T. Osmotic pressure of *Noctiluca scintillans*. Journ. Fac. Sci. Imp. Univ. Tokyo, Zool., III, 495—97, Tokyo, 1934.
Lang, K. Beiträge zur Kenntnis der Harpacticiden. IV, V und VI. Zool. Anz., CXIV, Heft 1/2, 33—40; Heft 3/4, 65—68; und Heft 5/6, 133—36; Leipzig, 1936.
Lebour, M. V. Notes on the Eggs and Larvae of Some Plymouth Prosobranchs. Journ. Mar Biol. Assoc. U. K., N. S. XX, 547—66, Plymouth. 1936.

Leloup, E. Les Siphonophores de la Rade de Villefranche-sur-Mer (Alpes Maritimes, France). Bull. Mus. Roy. d'Hist. Nat. de Belgique, XI, No. 31, Bruxelles, 1935.

Leloup, E. Hydropolypes calyptoblastiques et Siphonophores récoltés au cours de la Croisière (1934—1935) du navire-école belge "Mercator". Bull. Mus. d'Hist. Nat. de Belgique, XI, No. 34, Bruxelles, 1935.

Leloup, E. und Hentschel, E. Die Verbreitung der calycophoren Siphonophoren im Südatlantischen Ozean. Wiss. Ergebn. deutsch. atlant. Exped. a. d. Forsch.- und Vermessungsschiff "Meteor" 1925—1927, Bd. XII, Teil II, Berlin und Leipzig, 1935.

Nielsen, E. S. The Production of Phytoplankton at the Faroe Isles, Iceland, East Greenland and in the Waters around. Medd. Komm. Danmarks Fisk.- og Havunders., Ser. Plankton, Vol. III, Nr. 1, København, 1935.

Russell, F. S. Observations on the Distribution of Plankton Animal Indicators made on Col. E. T. Peel's Yacht "St. George" in the Mouth of the English Channel, July, 1935. Journ. Mar. Biol. Assoc. U. K., N. S., XX, 507—22, Plymouth, 1936.

Russell, F. S. On a New Species of Medusa, *Eucheilota hartlaubi*, n. sp. Journ. Mar. Biol. Assoc. U. K., N. S. XX, 589—94, Plymouth, 1936.

Russell, F. S. A Review of some Aspects of Zooplankton Research. Cons. Perm. Internat. p. l'Explor. de la Mer. Rapp. et Proc.-Verb., XCV, 3—30, Copenhague, 1936.

Seiwell, H. R. The Annual Organic Production and Nutrient Phosphorus Requirement in the Tropical Western North Atlantic. Woods Hole Oceanogr. Inst., Nr. 24, 20—32, U. S. A., 1935.

Sexton, E. W. and Clark, A. R. Variations in the White Pigment of the Eye in *Gammarus chevreuxi* Sexton, with a Description of a New Genetic Type, the "Clotted Eye". Journ. Mar. Biol. Assoc. U. K., N. S. XX, 691—700, Plymouth, 1936.

Smirnov, S. Beschreibung einer neuen *Acartia* Art aus dem Japanischen Meer nebst einigen Bemerkungen über die Untergattung *Eucartia* Steuer. Zool. Anz., CXIV, Heft 3/4, 87—92, Leipzig, 1936.

Steuer, A. Die Entwicklung der deutschen marinen Planktonforschung. Naturwissenschaften, XXIV, 129—31, Berlin, 1936.

Thiel, M. E. Die Besiedlung des südatlantischen Ozeans mit Hydromedusen. Wiss. Ergebn. deutsch. atlant. Exped. a. d. Forsch.- und Vermessungsschiff "Meteor" 1925—1927, Bd. XII, Teil II, 32—100, Berlin und Leipzig, 1935.

Zabelina, M. M.. Some new data on the phytoplankton of the Kara Sea. Inst. Hydrol. Explor. Mers. U. R. S. S., XIII, 105—43, 1931. (In Russian, English résumé).

CONDITIONS OF PRODUCTION IN THE SEA

Krogh, A. Conditions of life in the ocean. Ecol. Monogr., IV, 421—29, Durham, N. C., 1934.

Krogh, A. Conditions of life at great depths in the ocean. Ecol. Monogr., IV, 430—39, Durham, N. C., 1934.

Picotti, M. I fattori chimici essenziali "al minimo" determinanti per lo sviluppo e la capacità biologica marina ed il loro controllo immediato. Boll. Pesca, Piscicolt. et Idrobiol., XI, 826—37, Roma, 1935.

Tait, J. B. Fluctuations in our Catches of Marketable Fish. Fishing News, 24—25, Aberdeen, 29—II—36.

Marine Bacteria.

Bertel, R. Les bactéries marines et leur influence sur la circulation de la matière dans la mer. Bull. Inst. Océanogr., No. 687, Monaco, 1936.

Bertel, L. Sur quelques avantages remarquables dans la culture des bactéries marines. Bull. Inst. Océanogr., No. 688, Monaco, 1936.

Keys, A., Christensen, E. H. and Krogh, A. The Organic Metabolism of Sea-Water with Special Reference to the Ultimate Food Cycle in the Sea. Woods Hole Oceanogr. Inst., No. 79, 181—96, U. S. A., 1935.

Selman, W. A. and Carey, C. L. Decomposition of Organic Matter in Sea Water by Bacteria. II. Influence of Addition of Organic Substances upon Bacterial Activities. Journ. Bacteriol., XXIX, 545—61, Baltimore, 1935.

Waksman, S. A. and Carey, C. L. Decomposition of Organic Matter in Sea Water by Bacteria. I. Bacterial Multiplication in Stored Sea Water. Journ. Bacteriol., XXIX, 531—43, Baltimore, 1935.

Marine Plants.

Bachrach, E. et Simonet, M. Le phénomène du bleuissement chez les Diatomées. Etude expérimentale. Rev. Trav. Office Pêches Marit., T. IX, 113—16, Paris, 1936.
Boury, M., le Gall, J., Lambert, L., Rémy, D. et Schvinte, J. Manuel des Pêches Maritimes Françaises. Utilisation des Plantes marines. Industrie des Algues. Mém. de l'Office des Pêches Marit. (Sér. Spéc.), Fasc. IV, No. 12, 65—88, Paris, 1936.
Cotton, A. D. Changes in the British Fauna during the past fifty years. Marine Algae. Proc. Linn. Soc. London, CXLVIII, 45—49, London, 1935.
Doyle, W. L. Cytology of *Valonia*. Pap. from the Tortugas Lab., XXIX, 13—21, Washington, D. C., 1936.
Heilbron, I., Phipers, R. F. and Wright, H. R. The chemistry of the algae. I. The algal sterol fucosterol. Journ. Chem. Soc., 1572—576, London, 1934.
Isaac, W. E. Some observations and experiments on the drought resistance of *Pelvetia canaliculata*. Ann. Botany, XLVII, 343—48, London, 1933.
Kopac, M. J. Electrical Resistance of *Valonia*. I: Changes in Resistance with Time in impaled Coenocytes. Pap. from the Tortugas Lab., XXIX, 359—86, Washington, D. C., 1936.
Lewis, E. A. An Investigation of the Seaweeds within a Marked Zone of the Shore at Aberystwyth, during the Year 1933—34. (With Special Reference to the Use of the Spores as Food for Oyster Larvae). Journ. Mar. Biol. Assoc. U. K., N. S. XX, 615—20, Plymouth, 1936.
Lovern, J. A. Fat Metabolism in Fishes. IX. The Fats of some aquatic plants. Biochem. Journ., XXX, 387—90, London, 1936.
Parke, M. W. Algological Records for the Manx Region. Rep. for 1934 (No. 47) Mar. Biol. Stat. Port Erin, Isle of Man, 29—36, Liverpool, 1934.
Vouk, V. Studien über adriatische Codiaceen. Acta Adriatica Inst. Biol. Oceanogr. Split, No. 8, Split, 1936.

Bottom Deposits.

Correns, C. W. Die Verfahren der Gewinnung und Untersuchung der Sedimente. Wiss. Ergebn. deutsch. Atlant. Exped. a. d. Forsch.- und Vermessungsschiff "Meteor" 1925—1927, Bd. III, Teil III, 1—42, Berlin und Leipzig, 1935.
Pratje, O. Gewinnung und Bearbeitung der Bodenproben. Wiss. Ergebn. deutsch. Atlant. Exped. a. d. Forsch.- und Vermessungsschiff "Meteor" 1925—1927, Bd. III, Teil II, Berlin und Leipzig, 1935.
Schott, W. Die Foraminiferen in dem äquatorialen Teil des Atlantischen Ozeans. Wiss. Ergebn. deutsch. Atlant. Exped. a. d. Forsch.- und Vermessungsschiff "Meteor" 1925—1927, Bd. III, Teil III, 43—134, Berlin und Leipzig, 1935.
Stetson, H. C. and Schalk, M. Marine Erosion of Glacial Deposits in Massachusetts Bay. Journ. Sediment. Petrol., V, 40—51, Tulsa, 1935.
Thamdrup, H. M. Beiträge zur Ökologie der Wattenfauna auf experimenteller Grundlage. Medd. Komm. Danmarks Fisk.- og Havunders., Ser. Fiskeri, Vol. X, Nr. 2, København, 1935.
Thorp, E. M. Calcareous Shallow-Water Marine Deposits of Florida and the Bahamas. Pap. from the Tortugas Lab., XXXIX, 37—143, Washington, D. C., 1936.
Vaughan, T. W. Studies of marine bottom deposits at the Scripps Institution of Oceanography. Bull. Nat. Res. Council, No. 98, Washington, D. C. 1935.

Bottom Fauna.

GENERAL

Aikawa, H. Nature of benthic faunas of the Continental Shelf around Japan, with reference to neritic fisheries. Journ. Imp. Fish. Exper. Stat., VII, 183—207, Tokyo, 1936. (In Japanese, English résumé).
Anon. Deterioration of Structures in Sea-Water. Dept. Sci. and Indust. Res., 15th Rep., London, 1935.
Bohn, G. Les Invertébrés (Coelentérés et vers). Actualités Sci. et Indust., CXXXIII, 3—102, Paris, 1934.
Broch, H. Some Zoogeographical Problems of the Northern Pacific. Science, N. S. LXXXIII, 101, U. S. A., 1936.
Fage, L. et Monod, Th. La faune marine du Jameo de Agua, lac souterrain de l'île Lanzarote (Canaries). Arch. Zool. Expér. et Gén., LXXVIII, 97—113, Paris, 1936.

Idelson, M. S. Preliminary quantitative evaluation of the bottom fauna of the Spitzbergen bank. Ber. Wiss. Meeresinst., IV, 27—46, Moscow, 1930. (In Russian, English résumé).
Manton, S. M. Ecological Surveys of Coral Reefs. Great Barrier Reef Exped. 1928—29, Sci. Rep. Brit. Mus. (Nat. Hist.), III, No. 10, London, 1935.
Moore, H. B. New Faunistic records for the Manx Region. Rep. for 1934 (No. 47) Mar. Biol. Stat. Port Erin, Isle of Man, 27—28, Liverpool, 1934.
Spärck, R. Review of the Danish Investigations on the Quantitative Composition of the Bottom Fauna in Iceland and Greenland Waters. Cons. Perm. Internat. p. l'Explor. de la Mer. Rapp. et Proc.-Verb., XCIX, V, Copenhague, 1936.
Stephenson, T. A. The marine ecology of the South African coasts, with special reference to the habits of limpets. Proc. Linn. Soc. London, CXLVIII, 74—79, London, 1936.
Taliev, D. N. i Bazikalova, A. I. Preliminary results of a comparison of the Baikal and Caspian faunas by the method of precipitin reaction. C. R. Acad. Sci. U. R. S. S., II, 512—17, Leningrad, 1934. (In Russian, English résumé).
Thamdrup, H. M. Beiträge zur Ökologie der Wattenfauna auf experimenteller Grundlage. Medd. Komm. Danmarks Fisk.- og Havunders., Ser. Fisk., X, Nr. 2, København, 1935.
Wasmund, E. Entwicklung und Verbesserung der Entnahmeapparatur für Bodenproben unter Wasser. Arch. Hydrobiol. et d'Ichthyol., XXIII, 646—62, Varsovie, 1932.

PHYSIOLOGY AND BEHAVIOUR

Barnes, T. C. Experiments on *Ligia* in Bermuda. IV. The Effects of Heavy Water and Temperature. Biol. Bull., Woods Hole, Mass., LXX, 109—17, U. S. A., 1936.
Coe, W. R. Sex ratios and sex changes in Molluscs. Mém. Mus. Roy. d'Hist. Nat. de Belgique, 2e sér., Fasc. 3, 69—76, Bruxelles, 1936.
Day, J. H. Heterogenic Growth in the Abdomen of *Carcinus maenas*. Dove Mar. Lab. Rep. for the year ending 31st July, 1935, 3rd Ser., No. 3, 49—59, Newcastle-on-Tyne, 1935.
Eriksson, S. Studien über die Fangapparate der Branchiopoden nebst einigen phylogenetischen Bemerkungen. Zool. Bidrag. fr. Uppsala, XV, 23—288, Uppsala. 1936.
Fowler, L. H. Relative effect of biologically conditioned and other extremely hypotonic water on the tissues of the marine turbellarian, *Procerodes wheatlandi*. Physiol. Zool., VIII, 228—45, Chicago. 1935.
Fox, H. M. Metabolism of Cold-Blooded Animals in Different Latitudes. Nature, CXXXVII, 903—04, London, 1936 .
Henschel, I. Untersuchungen über den chemischen Sinn der Scyphomedusen *Aurelia aurita* und *Cyanea capillata* und der Hydromeduse *Sarsia tubulosa*. Wiss. Meeresunters. N. F., Abt. Kiel, XXII, 21—42, Kiel und Leipzig, 1936.
Kessel, E. Über den Bau der *Haliotis*-Schale. III. Zool. Anz., CXIII, 290—99, Leipzig, 1936.
Lucke, J. B. Bottom conditions in a tidal lagoon. Journ. Paleontol., IX, 101—07, Chicago, 1935.
Macdonald, R. A study of symmetry in the Centrechinoidea, based on behaviour, with special reference to *Lytechinus variegatus;* including a short discussion of linguistic difficulties in describing biological phenomena. Proc. Amer. Phil. Soc., LXXVI, 87—123, Philadelphia, 1936.
Marceau, F. Sur quelques propriétés spéciales des muscles adducteurs des Mollusques acéphales en rapport avec leur disposition et leur structure. Mém. Mus. Roy. d'Hist. Nat. de Belgique, 2e sér., Fasc. 3, 941—76, Bruxelles, 1936.
Pantin, C. F. A. On the Excitation of Crustacean Muscle: III. Quick and Slow Responses. IV. Inhibition. Journ. Exper. Biol., XIII, 148—69, London, 1936.
Parker, G. H. Direction and means of locomotion in the regular sea-urchin *Lytechinus*. Mém. Mus. Roy. d'Hist. Nat. de Belgique, 2e sér., Fasc. 3, 197—208, Bruxelles, 1936.
Pora, E. A. Sur les Différences Chimiques et Physico-Chimiques du Sang des deux sexes de quelques invertébrés marins. Bull. Inst. Océanogr., No. 689, Monaco, 1936.
Runnström, S. Die Anpassung der Fortpflanzung und Entwicklung mariner Tiere an die Temperaturverhältnisse verschiedener Verbreitungsgebiete. Bergens Mus. Årbok (Naturvid. Rekke) 1936, 1. Hefte, Nr. 3, Bergen, 1936.
Sawano, E. Contributions to the Knowledge on the Digestive Enzymes in Marine Invertebrates. I. Proteolytic Enzymes in *Polypus vulgaris* (Lamarck). Preliminary Reports. Sci. Rep. Tokyo Bunrika Daigaku, Sec. B, II, 101—26, Tokyo, 1935.
Strohl, J. La bipolarité de la faune marine et les données actuelles de la Génétique. Suivi de considérations générales sur les relations de la taxonomie avec la

physiologie et la génétique. Mém. Mus. Roy. d'Hist. Nat. de Belgique, 2e sér., Fasc. 3, 311—18, Bruxelles, 1936.

Verlaine, L. L'instinct et l'intelligence chez les Mollusques. Les Gastéropodes perceurs de coquilles. Mém. Mus Roy. d'Hist. Nat. de Belgique, 2e sér., Fasc. 3, 387—94, Bruxelles, 1936.

Welsh, M. Oxygen production by Zooxanthellae in a Bermudan Turbellarian. Biol. Bull., Woods Hole, Mass., LXX, 282—87, U. S. A., 1936.

Welsh, J. H. Diurnal Movements of the eye pigments of *Anchistioides*. Biol. Bull., Woods Hole, Mass., LXX, 217—27, U. S. A., 1936.

Yonge, C. M. The evolution of the swimming habit in the Lamellibranchia. Mém. Mus. Roy. d'Hist. Nat. de Belgique, 2e sér., Fasc. 3, 77—100, Bruxelles, 1936.

SPECIAL GROUPS

Abramowitz, A. A. Color Changes in Cancroid Crabs of Bermuda. Proc. Nat. Acad. Sci., XXI, 677—81, Washington, 1935.

Adam, W. et Leloup, E. Les *Crepidula* de la côte occidentale de l'Afrique. Mém. Mus. Roy. d'Hist. Nat. de Belgique, 2e sér., Fasc. 3, 349—68, Bruxelles, 1936.

André, M. Sur le *Cancer personatus* Linné. Bull. Mus. Nation. d'Hist. Nat., 2e sér., VIII, 92—93, Paris, 1936.

Bayer, C. Sur une difformité du *Cassis cornuta* (L.) causée par des Balanes. Mém. Mus. Roy .d'Hist. Nat. de Belgique, 2e sér., Fasc. 3, 41—42, Bruxelles, 1936.

Berkeley, E. and Berkeley, C. Some notes on the polychaetous annelids of Elkhorn slough, Monterey Bay, California. Amer. Midland Naturalist, XVI, No. 5. Notre Dame, Ind., 1935.

Borg, F. Einige Bemerkungen über Brackwasserbryozoen. Zool. Anz., CXIII, 188—93, Leipzig, 1936.

Boschma, H. Sur la croissance de quelques Coraux des récifs de l'île d'Edam (Baie de Batavia). Mém. Mus. Roy. d'Hist. Nat. de Belgique, 2e sér., Fasc. 3, 101—14, Bruxelles, 1936.

Cannon, H. G. On the Rock-boring Barnacle, *Lithotrya valentiana*. Great Barrier Reef Exped. 1928—29, Sci. Rep. Brit. Mus. (Nat. Hist.), V, No. 1, London, 1935.

Cornwall, I. E. On the nervous system of four British Columbian barnacles (one new species). Journ. Biol. Board Canada, I, 469—75, Toronto, 1935.

Cuénot, L. Commensalisme des pontes de Céphalopodes avec des Eponges et des Cnidaires. Mém. Mus. Roy. d'Hist. Nat. de Belgique, 2e sér., Fasc. 3, 37—40, Bruxelles, 1936.

Damas, D. Une Narcoméduse parasite d'un ver polychète. Mém. Mus. Roy. d'Hist. Nat. de Belgique, 2e sér., Fasc. 3, 1177—197, Bruxelles, 1936.

Deichmann, E. The Arctic Species of *Molpadia* (Holothuroidea), and some remarks on Heding's attempt to subdivide the Genus. Ann. and Mag. Nat. Hist., 10th ser., XVII, 452—64, London, 1936.

Duboscq, O. and Tuzet, O. Les Amoebocytes et les cellules germinales des Eponges calcaires. Mém. Mus. Roy. d'Hist. Nat. de. Belgique, 2e sér., Fasc. 3, 209—26, Bruxelles, 1936.

Fauré-Frémiet, E. La famille des *Folliculinidae (Infusoria heterotricha)*. Mém. Mus. Roy. d'Hist. Nat. de Belgique, 2e sér., Fasc. 3, 1129—176, Bruxelles, 1936.

Foyn, B. Foraminiferstudien. I. Der Lebenszyklus von *Discorbina vilardeboana* d'Orbigny. Bergens Mus. Årbok (Naturvid. Rekke) 1936, 1. Hefte, Nr. 2, Bergen. 1936.

Foxon, G. E. H. Notes on the Natural History of certain Sanddwelling Cumacea. Ann. and Mag. Nat. Hist., 10th ser., XVII, 377—93, London, 1936.

Fraser, C. M. Hydroids from the West Coast of Vancouver Island. Canad. Field Naturalist, XLIX, No. 9, Ottawa, 1935.

Fraser, C. M. Hydroids from the Queen Charlotte Islands. Journ. Biol. Board Canada, I, 503—07, Toronto, 1935.

Fraser, J. H. The Occurrence, Ecology and Life History of *Tigriopus fulvus* (Fischer). Journ. Mar. Biol. Assoc. U. K., NS. XX, 523—36, Plymouth, 1936.

Fraser, J. H. The distribution of rock pool Copepoda according to tidal level. Journ. Anim. Ecol., V, 23—28, London, 1936.

Gudger, E. W. Coelenterates as enemies of fishes. II. Jelly-fishes as fish-eaters. Bull. New York Zool. Soc., XXXVII, 47—58, New York, 1934.

Gurjanova, E. Neue Beiträge zur Fauna der Crustacea-Malacostraca des arktischen Gebietes. Zool. Anz., CXIII, 245—55, Leipzig, 1936.

Harant, H. *Nephrococcidioides* n. gen. Mycochyridinée parasite des Styélidés (Ascidies stolidobranches). Bull. Inst.. Océanogr., No. 690, Monaco, 1936.

Hickson, S. J. Darwin's *Cavernularia*. Nature, CXXXVII, 909, London, 1936.

Huus, J. Ascidiologische Notizen. II. Über den Fund von *Styela atlantica* (Van Name) an der norwegischen Westküste, mit Bemerkungen über die amphiatlantische Verbreitung einiger Ascidien. Bergens Mus. Årbok (Naturvid. Rekke) 1936, 1. Hefte, Nr. 5, Bergen, 1936.

Kapelus, F. F. The Anatomy of the Enteropneust *Saccoglossus inhacensis* sp. n. Ann. Natal Mus., VIII, Part 1, 47—94, London, 1936.

Kerr, J. G. Notes upon the Dana Specimens of *Spirula* and upon certain problems of Cephalopod Morphology. Danish "Dana" Exped. 1920—22, No. 8, Copenhagen, 1931.

Klugh, A. B. and Newcombe, C. L. Light as a controlling factor in the growth of *Balanus balanoides*. Canad. Journ. Res., XIII, 39—44, Ottawa, 1935.

von Kolosváry, G. Die Echinodermaten-Sammlung des Ungarischen National-Museums. Folia Zool. et Hydrobiol., IX, 76—114, Riga, 1936.

Kubo, I. A new Decapod Crustacean from Japan, *Paramja kominatoensis*, gen. et sp. nov. Bull. Japan. Soc. Sci. Fish., IV, 361—64, Tokyo, 1936.

Kunz, H. Eine neue Suctoria, *Cucumophrya leptomesochrae* n. g., n. sp., von Helgoland. Zool. Anz., CXIV, Heft 7/8, 173—74, Leipzig, 1936.

Labbe, A. La phylogénie possible des Silicodermés. Mém. Mus. Roy. d'Hist. Nat. de Belgique, 2e sér., Fasc. 3, 15—22, Bruxelles, 1936.

Lameere, A. Histoire de la Classification des Mollusques. Mém. Mus. Roy. d'Hist. Nat. de Belgique, 2e sér., Fasc. 3, 1—12, Bruxelles, 1936.

Lamy, E. Emissions sonores produites par des Mollusques. Mém. Mus. Roy. d'Hist. Nat. de Belgique, 2e sér., Fasc. 3, 31—36, Bruxelles, 1936.

Lang, K. Beiträge zur Kenntnis der Harpacticiden. III. Zool. Anz., CXIII, 174—77, Leipzig, 1936.

de Laubenfels, M. W. A discussion of the Sponge Fauna of the Dry Tortugas in Particular and the West Indies in General, with material for a Revision of the Families and Orders of the Porifera. Pap. from Tortugas Lab., XX, Washington, D. C., 1936.

Leloup, E. Hydropolypes calyptoblastiques et Siphonophores récoltés au cours de la Croisière (1934—1935) du navire-école belge "Mercator". Bull. Mus. d'Hist. Nat. de Belgique, XI, No. 34, Bruxelles, 1935.

Leloup, E. Hydraires Calyptoblastiques des Indes Occidentales. Mém. Mus. Roy. d'Hist. Nat. de Belgique, 2e sér., Fasc. 2, Bruxelles, 1935.

Longchamps, M. de S. A propos de la torsion de la queue chez les Urochordes. Mém. Mus. Roy. d'Hist. Nat. de Belgique, 2e sér., Fasc. 3, 349—68, Bruxelles, 1936.

Loosanoff, V. Sexual phases in the Quohog. Science, N. S., LXXXIII, 287—88, U. S. A., 1936.

Moll, F. Le teredini del Mediterraneo dal punto di vista tecnico. Boll. Pesca, Piscicolt. e Idrobiol., XI, 838—43, Roma, 1935.

Moore, H. B. The Biology of *Echinocardium cordatum*. Journ. Mar. Biol. Assoc. U. K., N. S. XX, 655—72, Plymouth, 1936.

Moore, H. B. The Biology of *Balanus balanoides*. V. Distribution in the Plymouth Area. Journ. Mar. Biol. Assoc. U. K., N. S. XX, 701—16, Plymouth, 1936.

Mortensen, Th. Echinoidea and Ophiuroidea. Discovery Rep., XII, 199—348, Cambridge, 1936.

Odhner, N. H. Nudibranchia Dendronotacea. A Revision of the System. Mém. Mus. Roy. d'Hist. Nat. de Belgique, 2e sér., Fasc. 3, 1057—128, Bruxelles, 1936.

Okada, Y. and Mawatari, Sh. Bryozoa Fauna Collected by the "Misago" during the Zoological Survey around Izu Peninsula (1). Sci. Rep. Tokyo Bunrika Daigaku, Sec. B, II, 127—47, Tokyo, 1935.

Orton, J. H. Experiments in the Sea on Rate of Growth of some Crustacea Decapoda. Journ. Mar. Biol. Assoc. U. K., N. S. XX, 673—90, Plymouth, 1936.

Orton, J. H. On the Rate of Growth *Sacculina carcini* Thompson in *Carcinus maenas* (Pennant). Ann. and Mag. Nat. Hist., 10th ser., XVII, 617—25, London, 1936.

Palombi, A. *Eugymnathea inquilina* nuova leptomedusa derivante da un atecato idroide ospite interno di *Tapes decussatus* L. Pubbl. Staz. Zool. di Napoli, XV, Fasc. 2, 159—68, Roma, 1936.

Perez, C. Atrophie des Glandes génitales de la Turritelle sous l'influence du parasitisme par les Sporocystes d'un Trématode. Mém. Mus. Roy. d'Hist. Nat. de Belgique, 2e sér., Fasc. 3, 539—48, Bruxelles, 1936.

Powers, P. B. A. Studies on the Ciliates of Sea-Urchins: A General Survey of the Infestations Occurring in Tortugas Echinoids. Pap. from the Tortugas Lap., XXIX, 293—326, Washington, D. C., 1936.

Pratje, O. Der Nachweis von Hebungen und Senkungen durch Koralleninseln. Natur und Volk, LXVI, 29—37, Frankfurt am Main, 1936.

Prenant, M. Sur un curieux complexe d'Astérie et de Donax. Mém. Mus. Roy. d'Hist. Nat. de Belgique, 2e sér., Fasc. 3, 413—14, Bruxelles, 1936.

Rees, W. J. Note on the ubiquitous Cercaria from *Littorina rudis*, *L. obtusata* and *L. littorea*. Journ. Mar. Biol. Assoc. U. K., N. S. XX, 621—24, Plymouth, 1936.
Remane, A. *Monobryozoon ambulans* n. g. n. sp., ein eigenartiges Bryozoon des Meeressandes. Zool. Anz., CXIII, 161—67, Leipzig, 1936.
Rhumbler, L. Rhizopoden der Kieler Bucht, gesammelt durch A. Remane. I. Teil. Schr. Naturw. Vereins f. Schleswig-Holstein, XXI, 143—94, Kiel, 1935.
Rothschild, M. Gigantism and Variation in *Peringia ulvae* Pennant 1777, caused by Infection with Larval Trematodes. Journ. Mar. Biol. Assoc. U. K., N. S. XX, 537—46, Plymouth, 1936.
Russell, F. S. On the Hydroid of *Laodicea undulata* (Forbes and Goodsir). Journ. Mar. Biol. Assoc. U. K., N. S. XX, 581—88, Plymouth, 1936.
Scatizzi, I. La pesca del corallo. Boll. Pesca, Piscicolt. e Idrobiol., XI, 706—26, Roma, 1935.
Schott, W. Die Foraminiferen in dem äquatorialen Teil des Atlantischen Ozeans. Wiss. Ergebn. deutsch. Atlant. Exped. a. d. Forsch.- und Vermessungsschiff "Meteor" 1925—1927, Bd. III, Teil III, 43—134, Berlin und Leipzig, 1935.
Stekhoven, J. H. S. Nématodes libres capturés entre les Hydraires dans le port de Plymouth. Bull. Mus. Roy. d'Hist. Nat. de Belgique, XI, No. 33, Bruxelles, 1935.
Stephensen, K. Pycnogonida from Norway and adjacent waters. Bergens Mus. Årbok (Naturvid. Rekke) 1935, 2. Hefte, Nr. 7, Bergen, 1936.
Thiel, M. E. Die Besiedlung des Südatlantischen Ozeans mit Hydromedusen. Wiss. Ergebn. deutsch. Atlant. Exped. a. d. Forsch.- und Vermessungsschiff "Meteor" 1925—1927, Bd. XII, Teil II, 32—100, Berlin und Leipzig, 1935.
Topsent, E. Eponges observées dans les parages de Monaco. (2e partie). Bull. Inst. Océanogr., No. 686, Monaco, 1936.
Wilson, D. P. The development of *Audouinia tentaculata* (Montagu). Journ. Mar. Biol. Assoc. U. K., N. S. XX, 567—80, Plymouth, 1936.
Wright, F. S. Report on the Maldon (Essex) Periwinkle Fishery. Min. Agric. and Fish., Fish. Invest., Ser. II, XIV, No. 6, London, 1936.
Wilson, C. B. Parasitic Copepods from the Dry Tortugas. Pap. from the Tortugas Lab., XXIX, 327—47, Washington, D. C., 1936.
Yonge, C. M. Studies on the Biology of Tortugas Corals. I. Observations on *Maeandra areolata* Linn. Pap. from the Tortugas Lab., XXIX, 185—98, Washington, D. C., 1936.
Yonge, C. M. Studies on the Biology of Tortugas Corals. II. Variations in the Genus *Siderastrea*. Pap. from the Tortugas Lab., XXIX, 199—208, Washington, D. C., 1936.

Fishery Investigations.

GENERAL

China. The Chekiang Provincial Fisheries Experiment Station. Spec. Publ. No. 1, Tinghai, Chekiang, 1936.
Clemens, W. A. Report of the Pacific Biological Station Nanaimo, B. C., for 1935. App. III to Ann. Rep. Biol. Board Canada for the Year 1935, 25—36, Ottawa, 1936.
le Danois, E. Rapport sur le fonctionnement de l'Office Scientifique et Technique des Pêches Maritimes pendant l'année 1935. Rev. Trav. Office des Pêches Marit., T. IX, 9—36, Paris, 1936.
Gilson, G. Recherches sur la Destruction du jeune Poisson par la Pêche Crevettière sur les Côtes de Belgique. Ann. Inst. d'Étud. Marit. d'Ostende, Mém. No. 3, Lierre, 1936.
Higgins, E. Progress in Biological Inquiries 1934. U. S. Dept. of Comm. Administrative Rep. No. 21, Washington, D. C., 1936.
Leim, A. H. Report of the Atlantic Biological Station St. Andrews, N. B. for 1935. App. I to Ann. Rep. Biol. Board Canada for the Year 1935, 7—16, Ottawa, 1936.
Lin, M. C. and Wu, Y. C. A Survey of the Fishery Industries of Ningpo. Bull. Chekiang Prov. Fish. Exper. Stat. Tinghai, II, No. 2, Chekiang, China, 1936. (In Chinese, English résumé).
N. America. Proceedings 1921—1930. N. Amer. Council on Fish. Invest., No. 1, Ottawa, 1932.
N. America. Proceedings 1931—1933. N. Amer. Council on Fish. Invest., No. 2, Ottawa, 1935.
Uda, M. Locality of Fishing Centre and Shoals of "Katuwo", *Euthynnus vagans* (Lesson), correlated with the contact zone of cold and warm currents. Bull. Japan. Soc. Sci. Fish., IV, 374—84, Tokyo, 1936.
U. S. A. Bulletin of the Mount Desert Island Biological Laboratory 1936. Thirty-Eighth Season.

COMMERCIAL FISHERIES

Anon. La conservation du poisson frais en "glace améliorée". Pêche Marit., Pêche Fluv. et Piscicult., XIX, 167—68, Paris, 1936.

Arcidiacono, F. Per una maggiore conoscenza della pesca con i consi (palamiti, palangresi) nel Golfo di Squillace. Boll. Pesca, Piscicolt. e Idrobiol., XII, 35—50, Roma, 1936.

Beaugé, Belloc, Boury, Desbrosses, Fage, le Gall, Lambert, Rémy et Schvinte. Manuel des Pêches Maritimes Françaises. Les Fonds de Pêche de l'Atlantique et les Ports du littoral Français. Mém. de l'Office des Pêches Marit. (Sér. Spéc.), Fasc. III, No. 11, Paris, 1936.

Boury, M., le Gall, J., Lambert, L., Rémy, D. et Schvinte, J. Manuel des Pêches Maritimes. Les Industries annexes de la Pêche. Mém. de l'Office des Pêches Marit., (Sér. Spéc.), Fasc. IV, No. 12, 19—90, Paris, 1936.

Carter, N. M. Report of the Pacific Fisheries Experimental Station Prince Rupert, B. C., for 1935. App. IV to Ann. Rep. Biol. Board Canada for the Year 1935, 37—46, Ottawa, 1936.

Denstedt, O. F. and Brocklesby, H. N. Fish Oils. VI. The structure and properties of pilchard oil films. Journ. Biol. Board Canada, II, 13—40, Toronto, 1936.

Denstedt, O. F. and Brocklesby, H. N. Fish Oils. V. The effect of various treatments on the rate of oxidation of pilchard oil. Journ. Biol. Board Canada, I, 487—96, Toronto, 1935.

Eichelbaum, E. Germany's increased production. Consumption also on up-grade; Nation will soon be independent of outside supplies. Fishing News, 35, Aberdeen, 13—VI—36.

England. The White Fish Industry. Second Report of Sea Fish Commission for the United Kingdom, London, 1936.

England. Sea Fisheries Statistical Tables 1935. Min. Agric. and Fish., London, 1936.

Finn, D. B. Report of the Atlantic Fisheries Experimental Station Halifax, N. S., for 1935. App. II to Ann. Rep. Biol. Board Canada for the Year 1935, 17—24, Ottawa, 1936.

Fischer, E. Die Anwendung neuerer Forschungen auf die Qualitätserhaltung der Seefische. Die deutsche Fischwirtschaft, III, 241—45, Berlin, 1936.

Ford, E. Great Britain's Sea Fish Supply. What intensive North Sea Fishing has shown. Fishing News, 16—17, Aberdeen, 9—V—36.

Ghio, B. A. America faces the same problem as Great Britain. Conservation in Californian Trawl Fisheries. Fishing News, 22, Aberdeen, 30—V—36.

Ireland. Report on the Sea and Inland Fisheries for the Year 1934. Dept. of Agric. Fish. Branch, Dublin, 1936.

Jarvis, N. D. and Griffiths, F. P. The Home Canning of Fishery Products. U. S. Bureau of Fish. Invest. Rep. No. 34, Washington, D. C., 1936.

Lin, S. Y. Fisheries of Tsien Tang Kiang. Bull. Chekiang Prov. Fish. Exper. Stat. Tinghai, II, No. 3, Chekiang, China, 1936. (In Chinese, English résumé).

Lundbeck, J. Die Erträge der Hochseefischerei im Jahre 1935. Die deutsche Fischwirtschaft, III, 65—66, Berlin, 1936.

Nellemose, W. A Review of Fishery Statistics in Relation to Wholesale-Index. Cons. Perm. Internat. p. l'Explor. de la Mer. Rapp. et Proc.-Verb., XCVIII, Copenhague, 1936.

Norway. Fiskeriene 1932. Offentlige foranstaltninger i fiskeribedriftens interesse. Årsberetn. vedk. Norges Fisk. 1932, Nr. 1, Bergen, 1934.

Salmon, J. La prolongation de la durée de conservation du poisson à l'état frais par l'ozone. Pêche Marit., Pêche Fluv. et Piscicult., XIX, 207—08, Paris, 1936.

Salmon, J. et le Gall, J. Application de l'ozone au maintien de la fraîcheur et à la prolongation de la durée de conservation du poisson frais. Rev. Trav. Office des Pêches Marit., IX, 57—66, Paris, 1936.

Scotland. Fifty-Fourth Annual Report of the Fishery Board for Scotland for the Year 1935. Edinburgh, 1936.

Scotland. Sea Fisheries Statistical Tables, 1935. Fish. Board for Scotland, Edinburgh, 1936.

Ségalis, J. Nouvelles méthodes de transport et de conservation du poisson vivant. Pêche Marit., Pêche Fluv. et Piscult., XIX, 87—88, Paris, 1936.

Spain. Estadistica de Pesca, Año 1933. Ministerio de Industria y Comercio, Madrid.

Spain. Estadistica de Pesca, Año 1934. Ministerio de Agricultura, Industria y Comercio, Madrid.

U. S. A. Bureau of Fisheries. Ann. Rep. Secretary of Comm. 1935. U. S. A., 1936.

FISHING GEAR

Anon. Problem of Mesh in Fishing. Fishing News, 6, Aberdeen, 25—IV—36.
Anon. Meshes experiments for Towing Nets. Fish. Invest. (Suppl. Rep.) Imp. Fish. Exper. Stat., No. 3, 1—13, Tokyo, 1936. (In Japanese).
Atkins, W. R. G. and Purser, J. The Preservation of Fishing Nets by Treatment with Copper Soaps and other substances. Journ. Mar. Biol. Assoc. U. K., N. S. XX, 627—42, Plymouth, 1936.
Lin, S. Y. Fisheries of Tsien Tang Kiang. Bull. Chekiang Prov. Fish. Exper. Stat. Tinghai, II, No. 3, Chekiang, China, 1936. (In Chinese, English résumé).
Miyamoto, H. The model experiments of sailing trawl net used in Makawa Bay. Bull. Japan. Soc. Sci. Fish., IV, 391—96, Tokyo, 1936.
Schnakenbeck, W. Die Verwendung des Echolotes zum Aufsuchen von Fischschwärmen. Der Fischmarkt, N. F. IV, 130—32, Cuxhaven, 1936.
Sugano, S. The Model Experiments on Fixed Nets for Fishing Salmon in Kamchatka. Bull. Japan. Soc. Sci. Fish., IV, 397—406, Tokyo, 1936.

Fish.

GENERAL

Ahl, E. Beschreibung eines neuen Fisches der Familie Atherinidae aus Celebes. Zool. Anz., CXIV, 175—77, Leipzig, 1936.
D'Ancona, U. Alcuni esemplari anomali di Batoidei adriatici. R. Com. Talassogr. Ital., Mem. CCII, Venezia, 1933.
Athanassopoulos, G. Sur un centre de concentration et de reproduction des poissons de mer dans les eaux hélleniques. Bull. Inst. Océanogr., No. 693, Monaco, 1936.
Berg, L. S. Rezente Klimaschwankungen und ihr Einfluss auf die geographische Verbreitung der Seefische. Zoogeographie, III, 1—15, Jena, 1935.
Bowman, A. Lemon Soles *(Pleuronectes microcephalus)*. Marking Experiments in Scottish Waters during the period 1919—1931. Fish. Scotland, Sci. Invest., 1935, No. 1, Edinburgh, 1936.
Cadenat, J. Les Serranidés de la Côte occidentale d'Afrique (du cap Spartel au cap Verd). Rev. Trav. Office des Pêches Marit., VIII, 377—423, Paris, 1935.
Coen, C. e Vatova, A. Malacofauna arupinensis. R. Com. Talassogr. Ital., Mem. CCII, Venezia, 1933.
Desbrosses, P. Contribution à la connaissance de la biologie du Rouget-Barbet en Atlantique Nord (III). *Mullus barbatus* (Rond) *Surmuletus* (Fage). Mode septentrional Fage. Rev. Trav. Office des Pêches Marit., VIII, 351—76, Paris, 1935.
Ehrenbaum, E. Naturgeschichte und wirtschaftliche Bedeutung der Seefische Nordeuropas. Handb. Seefisch. Nordeuropas (Lübbert u. Ehrenbaum), Bd. II, Stuttgart, 1936.
Fowler, H. The Marine Fishes of West Africa. Bull. Amer. Mus. Nat. Hist., LXX, Pt. 1, New York, 1936.
Järvi, T. H. Hajanaisia havaintoja. Suomen Kalastuslehti, XLIII, 95—98, Helsinki, 1936.
Johnsen, S. On the Variation of Fishes in Relation to Environment (Preliminary Account). Bergens Mus. Årbok (Naturvid. Rekke) 1936, 1. Hefte, Nr. 4, Bergen, 1936.
Marchand, J. M. The South African Marine Fishes of Commercial and Angling Importance. Fish. and Mar. Biol. Survey, Union of S. Africa, Fish. Bull. No. 2, Pretoria, 1935.
Meggitt, F. J. Reported Occurrence of European Fishes on the Tavoy Coast, Burma. Nature, CXXXVII, 908—09, London, 1936.
Norman, J. R. Reported Occurrence of European Fishes on the Tavoy Coast, Burma. Nature, CXXXVII, 321, London, 1936.
Norman, J. R. A new Fish of the Genus *Clupea* from Chile. Ann. and Mag. Nat. Hist., 10th Ser., XVII, 491—92, London, 1936.
Parr, A. E. Studies of Myctophinae in the Museum of Comparative Zoology. I. Revision of Type Specimens. II. Myctophinae Collected by C. O'D. Iselin in the North Atlantic in 1928. Bull. Mus. Comp. Zool., LXXVII, 43—65, Cambridge, Mass., 1934.
Svetovidov, A. N. *Lepidion schmidti*, eine neue Fischart. Zool. Anz., CXIII, 266—69, Leipzig, 1936.
Vladykov, V. D. Some unreported and rare fishes for the coast of Nova Scotia. Proc. Nova Scotian Inst. Sci., XIX, 1—8, Halifax, N. S., 1935.

Vladykov, V. D. Two new species of *Lumpenus lampetraeformis* (Walbaum) from North America. Rep. Newfoundland Fish. Res. Lab., Div. Fish. Res., Dept. Nat. Resources, II, 75—78, Newfoundland, 1935.
Vladykov, V. D. and McKenzie, R. A. The Marine Fishes of Nova Scotia. Proc. Nova Scotian Inst. Sci., XIX, 17—113, Halifax, N. S., 1935.

PHYSIOLOGY AND BEHAVIOUR

Breder, C. M. and Harris, J. E. Effect of Light on Orientation and Stability of Young Plectognath Fish. Pap. from the Tortugas Lab., XXIX, 23—36, Washington, D. C., 1936.
Bull, H. O. Studies on Conditioned Responses in Fishes. Part VI. The Formation of a Conditioned Motor Response in *Blennius pholis* L. to a Change in Direction of Current Flow. Dove Mar. Lab. Rep. for the year ending 31st July, 1935, 3rd Ser., No. 3, 37—48, Newcastle-on-Tyne, 1935.
Calzoni, M. Ricerche sulla placenta del *Carcharias glaucus*. Pubbl. Staz. Zool. di Napoli, XV, Fasc. 2, 169—74, Roma, 1936.
Chaisson, A. F. and Friedman, M. H. F. The effect of histamine, adrenaline and destruction of the spinal cord on the osmotic pressure of the blood in the skate. Proc. Nova Scotian Inst. Sci., XVIII, 240—44, Halifax, N. S., 1935.
Forbes, A. Flying Fish. Science, N. S. LXXXIII, 261—62, U. S. A., 1936.
Friedrich, H. Untersuchungen über das Blut und die Atmung der einheimischen Plattfische. II. Mitteilung. Die Blutgase von *Pleuronectes flesus* und *Pleuronectes platessa*. Wiss. Meeresunters, N. F., Abt. Kiel, XXII, 43—52, Kiel und Leipzig, 1936.
v. Frisch, K. und Dijkgraaf, S. Können Fische die Schallrichtung wahrnehmen? Zeitschr. vergleich. Physiol., XXII, 641—55, Berlin, 1935.
Grafflin, A. L. Renal Function in Marine Telesots. III. The Excretion of Urea. Biol. Bull., Woods Hole, Mass., LXX, 228—35, U. S. A., 1936.
Grafflin, A. L. and Gould, R. G. Renal Function in Marine Teleosts. II. The Nitrogenous Consistuents of the Urine of Sculpin and Flounder, with particular reference to Trimethylamine Oxide. Biol. Bull., Woods Hole, Mass., LXX, 16—27, U. S. A., 1936.
Gray, J. Studies in Animal Locomotion: IV. The Neuromuscular Mechanism of Swimming in the Eel. V. Resistance Reflexes in the Eel. Journ. Exper. Biol., XIII, 170—80 and 181—91, London, 1936.
Gray, J. and Sand, A. The Locomotory Rhythm of the Dogfisch *(Scyllium canicula)*. Journ. Exper. Biol., XIII, 192—99, London, 1936.
Gray, J. and Sand, A. Spinal Reflexes of the Dogfisch, *Scyllium canicula*. Journ. Exper. Biol., XIII, 200—09, London, 1936.
Henschel, J. Wasserhaushalt und Osmoregulation von Scholle und Flunder. Wiss. Meeresunters., N. F., Abt. Kiel, XXII, 89—121, Kiel und Leipzig, 1936.
Henschel, J. und Friedrich, H. Untersuchungen über das Blut und die Atmung der einheimischen Plattfische. I. Mitteilung. Die morphologische Beschaffenheit des Blutes der Nordsee-, Beltsee- und Ostseescholle. Wiss. Meeresunters., N. F., Abt. Kiel, XXII, 1—20, Kiel und Leipzig, 1936.
Hilditch, T. P. and Lovern, J. A. The Evolution of Natural Fats. Nature, CXXXVII, 478—81, London, 1936.
v. Holst, E. und le Mare, D. W. Bausteine zu einer vergleichenden Physiologie der lokomotorischen Reflexe bei Fischen. I. Mitteilungen. *Crenilabrus-Labrus, Sabrus, Uranoscopus*. Zeitschr. vergleich. Pysiol., XXIII, 223—36, Berlin, 1936.
Irving, L., Solandt, D. Y. and Solandt, O. M. Nerve Impulses from Branchial Pressure Receptors in the Dogfish. Journ. Physiol., LXXXIV, 187—90, London and Cambridge, 1935.
Leiner, M. Die physiologischen Grundlagen der Nachkommenfürsorge bei den Seenadeln (Syngnathidae). Zeitschr. vergleich. Physiol., XXIII, 147—207, Berlin, 1936.
Loeb, L. B. The "Flight" of Flying Fish. Science, N. S., LXXXIII, 260—61, U. S. A., 1936.
MacIntosh, F. C. The secretion of urea and chloride by the elasmobranch stomach. Journ. Biol. Board Canada, I, 497—501, Toronto, 1935.
Meader, R. G. The innervation of the muscle of accommodation in the eye of the Teleost, *Holocentrus*. Journ. Morphol., LIX. 163—72, Boston, 1936.
Mills, C. A. Propulsive Power Used by Flying Fish. Science, N. S., LXXXIII, 262, U. S. A., 1936.
Oppenheimer, J. M. Transplantation experiments on developing Teleosts. Journ. Exper. Zool., LXXII, 409—37, Philadelphia, 1936.

Pape, A. Beiträge zur Naturgeschichte von *Pleuronectes pseudoflesus*, eines Bastards zwischen Scholle und Flunder. Wiss. Meeresunters., N. F., Abt. Kiel, XXII, 53—88, Kiel und Leipzig, 1936.
Parker, G. H. Integumentary Color Changes in the Newly-born Dogfish *Mustelus canis*. Biol. Bull., Woods Hole, Mass., LXX, 1—7, U. S. A., 1936.
Petit, G. et Budker, P. Contribution à l'étude de la différenciation des dents cutanées, liées à la présence de cryptes sensorielles, chez quelques espèces de Sélaciens. Bull. Inst. Océanogr., No. 695, Monaco, 1936.
Reinhardt, F. Über Richtungswahrnehmung bei Fischen, besonders bei der Elritze (*Phoxinus laevis* L.) und beim Zwergwels (*Amiurus nebulosus* Raf.). Zeitschr. vergleich. Physiol., XXII, 570—603, Berlin, 1935.
Schmidt-Nielsen, S. und Flood, A. Die Trane einiger Squaliden. Analysenkonstante einiger marinen Tiere III. K. Norske Vid. Selskab. Forhandl., VI, 158—61, Trondhjem, 1933.
Schmidt-Nielsen, S. und Flood, A. Die Trane einiger Rochen und der Chimäre. Analysenkonstante einiger marinen Tiere IV. K. Norske Vid. Selskab. Forhandl., VI, 162—64, Trondhjem, 1933.
Sörensen, N. A. Die Farbstoffe des Tranes von *Orthagoriscus mola*. Lipochrome in den Fetten mariner Tiere III. K. Norske Vid. Selskab. Forhandl., VI, 154—57, Trondhjem, 1933.

EGGS AND LARVAE

Emmerie, A., van Eekelen, M. and Wolff, L. K. The Pigments from the Eggs of the Cod. Acta Brevia Neerland. Physiol., IV, 5—6, Amsterdam, 1934.
Pitotti, M. Sull'assorbimento del tuorlo negli embrioni di Torpedo. Pubbl. Staz. Zool. di Napoli, XV, Fasc. 2, 217—22, Roma, 1936.
Russell, F. S. The Seasonal Abundance of the Pelagic Young of Teleostean Fishes in the Plymouth Area. Part III. The Year 1935, with a Note on the Conditions as shown by the Occurrence of Plankton Indicators. Journ. Mar. Biol. Assoc. U. K., N. S. XX, 595—604, Plymouth, 1936.
Wimpenny, R. S. The Ova and Larvae of *Mugil capito* Cuv. from Lake Qarun, Egypt. Ann. and Mag. Nat. Hist., 10th Ser., XVII, 405—12, London, 1936.

FISH PARASITES AND DISEASES

Fukui, T. and Ogata, T. Note Brève sur un Nouveau Trématode. *Tetrochetus hamadai* provenant du *Spheroides spadiceus*. Sc. Rep. Tokyo Bunrika Daigaku, Sec. B, II, 149—54, Tokyo, 1935.
Sparta, A. Contributo alla conoscenza di uova, stadi embrionali e post-embrionali in *Macrorhamphosus scolopax* L. R. Com. Talassogr. Ital., Mem. CCXXV, Venezia, 1936.

AGE DETERMINATION

Wagler, E. Die Länge der Fische als Funktion des Alters. Allg. Fisch.-Zeit., LXI, 51—54, Augsburg, 1936.

PLAICE AND OTHER PLEURONECTIDS

Gilson, G. Recherches sur la Destruction du jeune Poisson par la Pêche crevettière sur les Côtes de Belgique. Ann. Inst. d'Étud. Marit. d'Ostende, Mém. No. 3, Lierre, 1936.
Kotthaus, A. Die Schollenbevölkerung der Deutschen Bucht im Jahre 1935. Journ. du Conseil, XI, 27—32, Copenhague, 1936.
Pape, A. Ein Plattfischbastard in der Ostsee und seine fischereiwirtschaftliche Bedeutung. Die deutsche Fischwirtschaft, III, 148, Berlin, 1936.
Thursby-Pelham, D. E. The Decline in the Lowestoft Plaice Fisheries. Journ. du Conseil, XI, 33—42, Copenhague, 1936.

HALIBUT

Jespersen, P. Investigations on the Stocks of Halibut in the North Atlantic. Cons. Perm. Internat. p. l'Explor. de la Mer. Rapp. et Proc.-Verb., XCIX, II, Copenhague, 1936.
Kask, J. L. The Experimental Marking of Halibut. Science, N. S., LXXXIII, 435—36, U. S. A., 1936.

COD

Meschkat, A. Untersuchungen über den Aufbau der Kabeljaunahrung im Bereich der Vestmannainseln. Cons. Perm. Internat. p. l'Explor. de la Mer. Rapp. et Proc.-Verb., XCIX, III, Copenhague, 1936.

HADDOCK

Anon. Haddock Research. Good prospects of better results soon. Fishing News, 7, Aberdeen, 30—V—36.

Porter, R. Young Haddocks. Grounds and effects of the current drifts. Fishing News, 11, Aberdeen, 29—II—36.

Raitt, D. S. North Sea and its Harvest: Great importance of the Haddock. Fishing News, 14, Aberdeen, 15—II—36.

TUNNY

Bouxin, J. et Legendre, R. La Fauna Pélagique de l'Atlantique recueillie dans des estomacs de Germons au large du Golfe de Gascogne. 2e partie: Céphalopodes. Ann. Inst. Océanogr. Monaco, N. S. XVI, Fasc. 1, Paris, 1936.

Coceani, B. L'industria delle tonnare e il mercato del tonno sott'olio. Boll. Pesca, Piscicolt. e Idrobiol., XI, 727—33, Roma, 1935.

Godsil, H. C. Tuna Tagging. Journ. du Conseil, XI, 94—97, Copenhague, 1936.

HERRING

Erdmann, W. Der deutsche Schleppnetzheringsfang 1935. Fischmarkt, N. F. IV, Heft 3, 60—81, Cuxhaven, 1936.

Farran, G. P. On the Mesh of Herring Drift-Nets in relation to the Condition Factor of the Fish. Journ. du Conseil, XI, 43—52, Copenhague, 1936.

Furnestin, J. Observations diverses sur les concentrations de harengs des "Fladen" (Mer du Nord). Rev. Trav. Office des Pêches Marit., IX, 47—56, Paris, 1936.

le Gall, J. Statistiques biologiques et considérations sur la population harenguière de la Manche Orientale et du Sud de la Mer du Nord (matériel prélevé en 1935). Rev. Trav. Office des Pêches Marit., IX, 37—46, Paris, 1936.

Hart, J. L. and Tester, A. L. Quantitative studies on herring spawning. Trans. Amer. Fish. Soc., LXIV, 307—13, New York, 1935.

Isle of Man. Manx Herring Fishery Report for 1935. Douglas, Isle of Man, 1936.

Lucas, C. E. On the Diurnal Variation of Size-Groups of Trawl-Caught Herring. Journ. du Conseil, XI, 53—59, Copenhague, 1936.

Runnstrøm, S. Investigations on Icelandic Herrings in 1929—35. Cons. Perm. Internat. p. l'Explor. de la Mer. Rapp. et Proc.-Verb., XCIX, IV, Copenhague, 1936.

Schmidt, U. Über den Heringsfang bei Helgoland. Fischmarkt, N. F. IV, 36—41, Cuxhaven, 1936.

Storrow, B. and Cowan, D. Herring Investigations. Dove Mar. Lab. Rep. for the year ending July 31st, 1935. 3rd Ser., No. 3, 11—26, Newcastle-on Tyne, 1936.

Tåning, Á. V. Distribution of Postlarval Stages of Herring in Icelandic Waters 1924—34. Cons. Perm. Internat. p. l'Explor. de la Mer. Rapp. et Proc.-Verb., XCIX, VI, Copenhague, 1936.

Wailes, G. H. Food of *Clupea pallasii* in southern British Columbian Waters. Journ. Biol. Board Canada, I, 477—86, Toronto, 1936.

Wendt, R. Die deutsche Heringsfischerei mit Treibnetzen im Jahre 1935. Fischmarkt, N. F. IV, 32—35, Cuxhaven, 1936.

PILCHARD, SPRAT AND ANCHOVY

Robertson, J. A. A Preliminary Account of the Sprat and Sprat Fishery in England. Journ. du Conseil, XI, 60—71, Copenhague, 1936.

Russo, A. Prodotto della pesca dei Clupeidi (acciuga, sardina, alaccia) nel golfo di Catania nel 1934—35. (dati riassuntivi e dati giornalieri). Boll. Pesca, Piscicolt. e Idrobiol., XII, 5—28, Roma, 1936.

Suyehiro, Y. On the various causes of mortality of Sardines. Journ. Imp. Fish. Exper. Stat., VII, 18—90, Tokyo, 1936. (In Japanese, English résumé).

Takayama, I. and Sakai, M. An Investigation of the present position of important fisheries. III. On the Sardine Fishery. Journ. Imp. Fish. Exper. Stat., VII, 287—334, Tokyo, 1936. (In Japanese, English résumé).

Uda, M. and Okamoto, G. Effect of oceanographic conditions on "Iwasi" (Sardine) fishing in the Japan Sea. Journ. Imp. Fish. Exper. Stat., VII, 18—49, Tokyo, 1936. (In Japanese, English résumé).

EELS

Athanassopoulos, G. La *Muraena unicolor* dans la Méditerranée. Bull. Inst. Océanogr., No. 691, Monaco, 1936.
Athanassopoulos, G. Sur la montée des civelles dans la Méditerranée orientale. Bull. Inst. Océanogr., No. 692, Monaco, 1936.
Athanassopoulos, G. Sur un centre de concentration et de reproduction des poissons de mer dans les eaux helléniques. Bull. Inst. Océanogr., No. 693, Monaco, 1936.
Bertin, L. Contributtions à l'étude des larves de Poissons Apodes (Les types de Strömman à l'Institut zoologique de l'Université d'Uppsala). Bull. Inst. Océanogr., No. 694, Monaco, 1936.
Chevey, P. Sur la présence du genre *Anguilla* en Indochine française. Bull. Mus. Nation. d'Hist. Nat., 2e sér., VIII, 65—68, Paris, 1936.
Hornyold, A. G. Le sexe, l'âge et la croissance de la petite Anguille de l'étang de Scamandre, dit des Iscles (Gard). Bull. Soc. Cent. d'Aquicol. et de Pêche, XLIII, 35—40, Paris, 1936.
Ladiges, W. Untersuchungen über den Aalbestand im hamburgischen Hafengebiet. Zeitschr. Fisch. u. d. Hilfswiss., XXXIV, 23—34, Berlin, 1936.

SKATES AND RAYS

Steven, G. A. Migrations and Growth of the Thornback Ray (*Raia clavata* L.). Journ. Mar. Biol. Assoc. U. K., N. S. XX, 605—14, Plymouth, 1936.
Walford, L. A. The Sharks and Rays of California. Div. Fish. and Game, Calif. Fish. Bull., No. 45, Sacramento, 1935.

FRESHWATER FISH

Altnöder, K. Die Wanderung der Ostseelachse. Die deutsche Fischwirtschaft, III, 259—60, Berlin, 1936.
Bayrakci, J. K. Die Schuppenentwicklung bei Süsswasserfischen und ihre örtlichen Verschiedenheiten. Int. Rev. d. ges. Hydrobiol., usw., XXXIII, Heft 1/2, 73—160, Leipzig, 1936.
Clemens, W. A. The age of maturity of sockeye salmon. Western Fish., X, No. 6, 1935.
Clemens, W. A. On the ages of maturity and the sex proportions of sockeye salmon in British Columbian waters. Trans. Roy. Soc. Canada, XXIX, 161—74, Ottawa, 1935.
Clemens, W. A. Report of the Pacific Biological Station Nanaimo, B. C., for 1935. App. III to Ann. Rep. Biol. Board Canada for the Year 1935, 35—36, Ottawa, 1936.
Davidson, F. A. and Shostrom, O. E. Physical and Chemical Changes in the Pink Salmon during the Spawning Migration. U. S. Bureau of Fish., Invest. Rep. No. 33, Washington, 1936.
Foerster, R. E. Fry Production from Eyed-egg Planting. Trans. Amer. Fish. Soc., LXIV, 379—81, New York, 1935.
Foerster, R. E. Inter-specific cross-breeding of Pacific salmon. Trans. Roy. Soc. Canada, XXIX, 21—33, Ottowa, 1935.
Foerster, R. E. and Pritchard, A. L. A study of the variation in certain meristic characters in the genus *Oncorhynchus* in British Columbia. Trans. Roy. Soc. Canada, XXIX, 85—95, Ottowa, 1935.
Hile, R. Age and Growth of the Cisco *Leucichthys artedi* (Le Sueur), in the Lakes of the Northeastern Highlands, Wisconsin. Bull. Bureau Fish., XLVIII, 211—317, Washington, 1936.
Huntsman, A. G. Factors influencing return of salmon from the sea. Trans. Amer. Fish. Soc., LXIV, 364—67, New York, 1935.
Huntsman, A. G. Report of the Margaree Salmon and Trout Investigations. App. V to Ann. Rep. Biol. Board Canada for the Year 1935, 47—48, Ottawa, 1936.
Järvi, T. H. Hajanaisia havaintoja. Suomen Kalastuslehti, XLIII, 17—22, 41—44, and 67—72, Helsinki, 1936.
Järvi, T. H. Merilohien vaellusten laajuus ja nopeus Norjan rannikolla. Suomen Kalastuslehti, XLIII, 92—94, Helsinki, 1936.
Järvi, T. H. and Menzies, W. J. M. The interpretation of the zones on scales of Salmon, Sea Trout and Brown Trout. Cons. Perm. Internat. p. l'Explor. de la Mer. Rapp. et Proc.-Verb., XCVII, Copenhague, 1936.
Leim, A. H. Report of the Atlantic Biological Station St. Andrews, N. B. for 1935. App. I to Ann. Rep. Biol. Board Canada for the Year 1935, 7—16, Ottawa, 1936.
Lovern, J. A. Fat Metabolism in Fishes. VIII. Changes in the Fat of Ripening Salmon Eggs. Biochem. Journ., XXX, 20—24, London, 1936.

MacFarlane, P. R. C. Salmon of the River Tay 1934. Fish. Scotland, Salmon Fish., No. V, Edinburgh, 1936.
Mottley, C. M. The origin and relations of the rainbow trout. Trans. Amer. Fish. Soc., LXIV, 323—27, New York, 1935.
Nall, G. H. Sea-Trout of the Kyle of Sutherland District, 1934—35. Fish. Scotland, Salmon Fish., 1936, No. I, Edinburgh, 1936.
Nall, G. H. Sea-Trout of the Laxford System. (Loch Stack and Loch More). Fish. Scotland, Salmon Fish., 1936, No. II, Edinburgh, 1936.
Otterstrøm, C. V. Die Turbinen und die abwärts wandernden jungen Lachse und Forellen (sowie Aale). Journ. du Conseil, XI, 72—93, Copenhague, 1936.
Otterstrøm, C. V. Saumon et Truite — directives pour leur différenciation. Bull. Français de Piscicult., Paris, 1935.
Pryce-Tannatt, T. E. Laws and Regulations in Summary Concerning Salmon and Trout Fisheries. Cons. Perm. Internat. p. l'Explor. de la Mer. Rapp. et Proc.-Verb., XCVI, Copenhague, 1936.
Ricker, W. E. and Robertson, A. Observations on the behaviour of adult sock-eye salmon during the spawning migration. Canad. Field Naturalist., XLIX, No. 8, Ottawa, 1935.
Staff, F. i Wilman, P. Vergleichende Studien über den einheimischen Charakter der grossen Maräne polnischer Seen. Inst. de Recherches des Forêts Domaniales, Ser. A, Nr. 16, Warszawa, 1936. (In Polish, German résumé).
Sugano, S. The Depth and the Distance from Shore of the Routes of Migration of Salmons. Bull. Japan. Soc. Sci. Fish., IV, 318—20, Tokyo, 1936. (In Japanese, English résumé).
Sugano, S. Immigration of Salmons to a Fishing Ground on the West Coast of Kamchatka in Relation to the Hydrographical Conditions. Bull. Japan. Soc. Sci. Fish., IV, 407—08, Tokyo, 1936.
Valli, J. i Järvi, T. H. Keskustelua chinook-lohesta. Suomen Kalastuslehti, LXII, 229—34, Helsinki, 1936.
White, H. C. The spawning period of brook trout, *S. fontinalis*. Trans. Amer. Fish. Soc., LXIV, 356—59, New York, 1935.
White, H. C. Some facts and theories concerning the Atlantic salmon. Trans. Amer. Fish. Soc., XLIV, 360—62, New York, 1935.

Freshwater and Pollution.

Alexander, W. B., Southgate, B. A. and Bassindale, R. Summary of the Tees Estuary Investigations. (Survey of the River Tees. Part II. The Estuary, Chemical and Biological). Journ. Mar. Biol. Assoc. U. K., N. S. XX, 717—24, Plymouth, 1936.
Legendre, J. Nocivité et utilité d'une eau usée industrielle. Bull. Soc. Cent. d'Aquicol. et de Pêche, XLIII, 30—32, Paris, 1936.
Scheuring, L. und Heuschmann, O. Über die Giftwirkung von Derris-präparaten auf Fische. Allg. Fisch. Zeit., LX, 370—78, Augsburg, 1935.
Smith, M. W. The dissolved oxygen content of fertilized waters. Trans. Amer. Fish. Soc., LXIV, 408—15, New York, 1935.

Oysters and other Lamellibranchs.

Anon. Introduction to the Rep. for 1934 (No. 47) Mar. Biol. Stat. Port Erin, Isle of Man, 3—5, Liverpool, 1934.
Bigger, J. W. The bacteriological examination of mussels. Journ. Hyg., XXXIV, 172—94, Cambridge, 1934.
Borde, F. Observation sur la production du naissain dans le Bassin d'Arcachon en 1935. Rev. Trav. Office des Pêches Marit., IX, 97—100, Paris, 1936.
Boury, M., le Gall, J., Lambert, L., Rémy, D. et Schvinte, J. Manuel des Pêches Maritimes. L'Ostréiculture, la Mytiliculture et la Conchyliculture. Mém. de l'Office des Pêches Marit. (Sér. Spéc.), Fasc. IV. No. 12, 91—165, Paris, 1936.
Bouxin, H. Technique d'élevage de deux palourdes comestibles (*Tapes decussatus* L. et *Tapes pullastra* Wood). Rev. Trav. Office des Pêches Marit., IX, 101—12, Paris, 1936.
Bunting, L. E., Eslick, A., Jones, J. W., and Orton, J. H. Rate of Growth of *Cardium edule*. Nature, CXXXVII, 705—06, London, 1936.
Chaux-Thévenin, H. Les claires expérimentales de l'Office Scientifique et Technique des Pêches Maritimes à la Tremblade. Rev. Trav. Office des Pêches Marit., IX, 83—96, Paris, 1936.

Chen, C. S. and Kao, T. P. Investigation into the cause of the premature death of the Razor Clam, *Sinovacula constricta* Lamark. Bull. Chekiang Prov. Fish. Exper. Stat. Tinghai, II, No. 1, Chekiang, China, 1936.
Herman, A. Rapport sur la reproduction des huîtres indigènes dans le Morbihan et le Finistère en 1935. Rev. Trav. Office des Pêches Marit., IX, 77—82, Paris, 1936.
Hewatt, W. G. Ecological succession in the *Mytilus californianus* habitat as observed in Monterey Bay, California. Ecology, XVI, 244—51, Brooklyn, 1935.
Higasi, H. Vitamin A content of oyster oil, and the isolation of a special sterol from its sterol fraction. Journ. Imper. Fish. Exper. Stat., VII, 209—31, Tokyo, 1936. (In Japanese, English résumé).
Hobson, A. D., Storrow, B., Leach, T. S. and Wright, F. S. A Survey of the Mussel Beds at Blyth, Budle Bay and Holy Island. Dove Mar. Lab. Rep. for the year ending 31st July, 1935, 3rd Ser., No. 3, 27—36, Newcastle-on-Tyne, 1935.
Lambert, L. La culture de la moule en Hollande. Rev. Trav. Office des Pêches Marit., VII, 431—67, Paris, 1935.
Orton, J. H. Observations and experiments on sex-change in the European Oyster, *Ostrea edulis* L. Mém. Mus. Roy. d'Hist., Nat. de Belgique, 2e sér., Fasc. 3, 997—1056, Bruxelles, 1936.
Ranson, G. L'absence de naissains d'huîtres portugaises en 1934 et 1935, dans la région de Marennes. Causes et conséquences. Rev. Trav. Office des Pêches Marit., T. IX, 67—76, Paris, 1936.
Satô, S. Ciliary Movement of the Gill of an Oyster, *Ostrea gigas*, in Relation to Temperature. Bull. Japan. Soc. Sci. Fish., IV, 409—10, Tokyo, 1936.
Warren, A. E. An ecological study of the sea mussel *(Mytilus edulis*, Linn.). Journ. Biol. Board Canada, II, 89—94, Toronto, 1936.
Wright, F. S. Report on Investigations into the Condition of certain of the Oyster Beds in the South Wales Sea Fisheries District. (June, 1934). Min. Agric. and Fish., Fish. Invest. Ser. II, XIV, No. 5, London, 1935.

Crustacea.

Anon. Die chinesische Wollhandkrabbe in Europa. I. Einleitung. Der Fischmarkt, N. F., IV, 99—101, Cuxhaven, 1936.
Dannevig, A. Hummer og Hummerkultur. Fiskeridirek. Skr., Ser. Havunders., Rep. Norwegian Fish. and Mar. Invest., IV, No. 12, Bergen, 1936.
Huxley, J. S. and Day, J. H. Progressive Change in the Form of Growth Gradients. Nature, CXXXVII, 668—69, London, 1936.
Israel, H. R. A contribution toward the life histories of two California Shrimps, *Crago franciscorum* (Stimpson) and *Crago nigricauda* (Stimpson). Div. Fish. and Game, Calif. Fish. Bull. No. 46, Sacramento, 1936.
Mantel, P. La pêche de la langouste aux Antilles par les pêcheurs bretons. Bull. Soc. d'Océanogr. de France, XVI, 1515—520 and 1528—530, Paris, 1936.
Orton, J. H. On the Rate of Growth of *Sacculina carcini* Thompson in *Carsinus maenas* (Pennant). Ann. and Mag. Nat. Hist., 10th ser., XVII, 617—25, London, 1936.
Panning, A. Die chinesische Wollhandkrabbe in Europa. III. Der Lebenskreislauf der Wollhandkrabbe. Der Fischmarkt, N. F. IV, 103—07, Cuxhaven, 1936.
Peters, N. Die chinesische Wollhandkrabbe in Europa. Der Fischmarkt, N. F. IV, 101—03, Cuxhaven, 1936.
Templeman, W. Local differences in the life history of the lobster *(Homarus americanus)* on the coast of the maritime provinces of Canada. Journ. Biol. Board Canada, II, 41—88, Toronto, 1936.
Thiel, H. Ist die Wollhandkrabbe ein Nahrungskonkurrent unserer Nutzfische? Fischmarkt, N. F. IV, 116—18, Cuxhaven, 1936.
Weymouth, F. W. and MacKay, D. C. G. Relative growth in the Pacific edible crab, *Cancer magister*. Preliminary Paper. Proc. Soc. Exper. Biol. and Med., XXXI, 1137—139, New York, 1934.

Whales and Seals.

Gray, J. Studies in Animal Locomotion: VI. The Propulsive Powers of the Dolphin. Journ. Exper. Biol., XIII, 192—99, London, 1936.
Hilditch, T. P. and Lovern, J. A. The Evolution of Natural Fats. Nature, CXXXVII, 478—81, London, 1936.
Irving, L., Fisher, K. C. and McIntosh, F. C. The water balance of a marine mammal, the seal. Journ. Cell. and Comp. Physiol., VI, 387—91, Philadelphia, 1935.

Irving, L., Solandt, O. M. and Fisher, K. C. Respiratory characteristics of the blood of the seal. Journ. Cell. and Comp. Physiol., VI, 393—403, Philadelphia, 1935.
Matsuura, Y. On the Lesser Rorqual found in the Adjacent Waters of Japan. Bull. Japan. Soc. Sci. Fish., IV, 325—30, Tokyo, 1936. (In Japanese, English résumé).
Oseki, T. Nutritive value of whale-liver. Bull. Inst. Phys. and Chem. Res., Japan, XIII, 1160—165, Tokyo, 1934. (In Japanese, English résumé).
Salvesen, H. K. Modern Whaling in the Antarctic. Journ. Roy. Soc. Arts, LXXXI, 403—23, London, 1933.
Steven, G. A. Seals *(Halichoerus grypus)* of Cornwall Coasts. Journ. Mar. Biol. Assoc. U. K., N. S. XX, 493—506, Plymouth, 1936.

Aquarium Equipment.

Martin, M. T. and Reid, D. M. A Tidal Aquarium System. Journ. Roy. Microscop. Soc., 3rd ser., LV, 245—48, London, 1935.

Biological-Miscellaneous.

Buchanan-Wollaston, H. J. The Philosophic Basis of Statistical Analysis (Contd.). Journ. du Conseil, XI, 7—26, Copenhague, 1936.
Richards, O. W. Analysis of the Constant Differential Growth Ratio. Pap. from the Tortugas Lab., XXIX, 171—83, Washington, D. C., 1936.

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